THE AMERICAN HEART JOURNAL

©Am. Ht. Assn.

A JOURNAL FOR THE STUDY OF THE CIRCULATION

PUBLISHED MONTHLY

UNDER THE EDITORIAL DIRECTION OF

THE AMERICAN HEART ASSOCIATION

Fred M. Smith - - - - - - **Editor-in-Chief**

Associate Editors

Hugh McCulloch

Irving S. Wright

Horace M. Korns

Editorial Board

EDGAR V. ALLEN
CLAUDE S. BECK
HARRY GOLDBLATT
GEORGE HERRMANN
WILLIAM J. KERR
ROBERT L. LEVY
H. M. MARVIN
JONATHAN C. MEAKINS
ROY W. SCOTT
ISAAC STARR
J. MURRAY STEELE
PAUL D. WHITE
FRANK N. WILSON
CHARLES C. WOLFERTH

VOLUME 18

JULY—DECEMBER, 1939

ST. LOUIS

THE C. V. MOSBY COMPANY

1939

COPYRIGHT, 1939, BY THE C. V. MOSBY COMPANY

(All rights reserved)

Printed in the United States of America

Press of
The C. V. Mosby Company
St. Louis

Medical
Wahr

The American Heart Journal

VOL. 18 JULY, 1939 No. 1

Original Communications

THE RELATION BETWEEN PROLONGED P-R INTERVAL AND AURICULAR FIBRILLATION IN PATIENTS WITH RHEUMATIC HEART DISEASE

M. D. ALTSCHULE, M.D.*
BOSTON, MASS.

PROLONGATION of the P-R interval in rheumatic fever has been shown by Bruenn[1] to be due, in most instances, to vagal activity, which depresses A-V conduction. Since it has been known for many years that vagal stimulation also predisposes to the development of auricular fibrillation,[2, 3, 4, 5] it was of interest to learn whether or not the incidence of that arrhythmia was unusually high in patients with rheumatic heart disease in whom evidence of increased vagal activity, as manifested by prolongation of the P-R interval, had been detected.

OBSERVATIONS

There were available for study the records of fifty-five patients with prolonged P-R intervals in whom a diagnosis of rheumatic heart disease had been established and in whom repeated electrocardiograms had been made. Twenty-one of these developed auricular fibrillation. For purposes of comparison the records of all patients with rheumatic heart disease and auricular fibrillation were also studied. These numbered 151, including the twenty-one who had a prolonged P-R interval.

In ten of the fifty-five patients with prolongation of the P-R interval to more than 0.21 seconds, the impaired A-V conduction occurred for a period of one to four days during a single attack of rheumatic fever, and was never again detected during the period of subsequent study, which varied from one month to three years. None of these patients developed auricular fibrillation.

Of the other forty-five patients of this group, a prolonged P-R interval was detected in all, or almost all, of the electrocardiograms, over a period ranging from one month to eight years. Twenty-one of these patients, or 47 per cent of the patients with a persistently prolonged

*From the Medical Research Laboratories of the Beth Israel Hospital and the Department of Medicine, Harvard Medical School, Boston.
Received for publication Nov. 25, 1938.

P-R interval, showed auricular fibrillation at one time or another. The remaining twenty-four, studied over periods ranging from one month to five years, at no time exhibited electrocardiographic evidence of auricular fibrillation, although, in two instances, paroxysms of arrhythmia, diagnosed clinically as auricular fibrillation, occurred from time to time; these two patients were not included in the fibrillation group, since electrocardiographic evidence of the arrhythmia was lacking.

Of the twenty-one patients who showed both auricular fibrillation and normal rhythm with prolonged P-R interval during their course, the fibrillation was paroxysmal, i.e., it lasted for a few hours to a few days, in five, and was chronic in sixteen. Of the sixteen cases of chronic auricular fibrillation, reversion to normal rhythm was effected in four cases, and a prolonged P-R interval then became evident. Fibrillation later recurred in these patients. In the remaining twelve cases of persistent auricular fibrillation, the onset of chronic auricular fibrillation was preceded by periods, ranging from one month to eight years, during which a prolonged P-R interval was found constantly, or almost so. Six of these patients were studied quite extensively; in all cases in this latter group, fibrillation occurred for periods of several weeks or months at a time, alternating with periods of normal rhythm, reversion taking place spontaneously. No relation was found in these cases between the onset and disappearance of auricular fibrillation or prolongation of the P-R interval, on the one hand, and symptoms of rheumatic infection, changes in degree of congestive failure, or medication, on the other. All six patients, when last seen, exhibited auricular fibrillation; there is no indication whether or not this arrhythmia is now permanently established. The following two patients (Table I), chosen because they were most carefully studied, illustrate the spontaneous variations in rhythm.

A definite increase in the percentage incidence of fibrillation was found in patients who showed prolongation of the P-R interval when the length of the period of observation following first appearance of the partial A-V block was increased.

An interesting phenomenon was observed in four of the patients with prolonged A-V conduction preceding the development of chronic auricular fibrillation; in these cases the onset of auricular fibrillation was associated with a high degree of auriculoventricular block, as manifested by idioventricular rhythm with a ventricular rate of approximately 50 beats per minute. Subsequently, the ventricular beating became quite irregular in all, although the rate remained slow.

Study of the 151 patients with rheumatic heart disease and auricular fibrillation revealed the fact that in 124 instances fibrillation was established when the patient was first seen, and remained so. Of twenty-seven patients in whom fibrillation developed under observation, twenty-one had previously shown prolongation of the P-R interval for periods ranging from one month to eight years.

The six patients in whom the onset of auricular fibrillation was not preceded by prolongation of the P-R interval are as follows:

1. Two cases in each of which a single electrocardiogram, showing normal rhythm, was obtained, respectively three and seven and one-half years before the onset of auricular fibrillation. These cases must be considered as inadequately studied.

TABLE I

CASES	DATE	ELECTROCARDIOGRAM (SECONDS)
Case 1		
	12/ 6/32	Normal Rhythm, P-R, .24
	12/30/32	Normal Rhythm, P-R, .18
	4/12/33	Normal Rhythm, P-R, .20
	4/ 3/34	Normal Rhythm, P-R, .22
	10/11/34	Normal Rhythm, P-R, .24
	1/15/35	Normal Rhythm, P-R, .24
	4/ 8/35	Normal Rhythm, P-R, .30
	6/19/35	Normal Rhythm, P-R, .24
	10/ 9/35	Normal Rhythm, P-R, .22
	1/ 3/36	Normal Rhythm, P-R, .24
	1/ 4/36	Normal Rhythm, P-R, .26
	1/ 8/36	Normal Rhythm, P-R, .24
	1/17/36	Normal Rhythm, P-R, .24
	6/29/36	Normal Rhythm, P-R, .24
	10/ 7/36	Normal Rhythm, P-R, .26
	6/ 1/37	Auricular Fibrillation
	6/ 2/37	Auricular Fibrillation
	6/ 8/37	Auricular Fibrillation
	6/21/37	Normal Rhythm, P-R, .26
	6/30/37	Normal Rhythm, P-R, .28
	7/13/37	Auricular Fibrillation
	7/14/37	Auricular Fibrillation
Case 2		
	4/12/33	Normal Rhythm, P-R, .22
	4/24/33	Normal Rhythm, P-R, .20
	5/ 4/33	Normal Rhythm, P-R, .24
	5/17/33	Normal Rhythm, P-R, .26
	5/24/33	Normal Rhythm, P-R, .24
	7/14/33	Normal Rhythm, P-R, .24
	8/14/33	Auricular Fibrillation
	8/17/33	Auricular Fibrillation
	8/19/33	Auricular Fibrillation
	9/25/33	Normal Rhythm, P-R, .28-.42
	12/19/33	Normal Rhythm, P-R, .24
	1/19/34	Normal Rhythm, P-R, .26
	4/24/34	Normal Rhythm, P-R, .22
	10/16/34	Normal Rhythm, P-R, .24
	2/16/35	Normal Rhythm, P-R, .24
	4/ 6/35	Normal Rhythm, P-R, .26
	11/ 9/35	Normal Rhythm, P-R, .26
	4/28/36	Normal Rhythm, P-R, .24
	9/23/36	Auricular Fibrillation
	11/14/36	Auricular Fibrillation
	4/24/37	Auricular Fibrillation
	12/ 4/37	Auricular Fibrillation

2. One case in which a very short P-R interval due to A-V nodal rhythm was found before the onset of fibrillation. Following the spontaneous disappearance of fibrillation, normal rhythm was associated with a prolonged P-R interval which persisted during the entire period of subsequent observation, lasting a month.

3. One case in which auricular fibrillation appeared three days after pulmonary infarction.

4. Two patients in whom a normal P-R interval was found constantly within a year preceding the onset of fibrillation. One of these was under the influence of quinidine at the time. In the other the fibrillation was paroxysmal and was apparently precipitated by the ingestion of alcohol.

DISCUSSION

In evaluating the significance of the frequent occurrence of auricular fibrillation in patients with rheumatic heart disease and evidence of increased vagal activity in the form of prolongation of the P-R interval, it is necessary to compare the incidence of fibrillation in the group studied here with that in groups of unselected cases of rheumatic heart disease. Grant,[6] in his follow-up studies of 1,000 patients, over a ten-year period, found that auricular fibrillation developed in 8 per cent. Calculation from the data of DeGraff and Lingg,[7] obtained in a ten-year study of patients with rheumatic heart disease, reveals its appearance in 9 per cent of patients who did not have it when first observed. The incidence of its appearance in the group of patients with prolongation of the P-R interval, who are the subject of this report, was four times as great. The difference between the incidence in the group with prolongation of the P-R interval here reported, and that of the unselected groups, is probably even greater, as some of the patients in the unselected groups who developed auricular fibrillation must have had a prolonged P-R interval. It must be concluded from the data here presented that patients with rheumatic heart disease who exhibit persistent prolongation of the P-R interval are prone to develop auricular fibrillation. Other authors, whose reports describe the development of auricular fibrillation either spontaneously or following the administration of digitalis in patients with partial A-V block, include Mackenzie,[8] Reid,[9] Schwartz,[10] Cookson,[11] Orgain, Wolff, and White,[12] and Tung.[13]

About half the patients with prolongation of the P-R interval in the present series did not develop auricular fibrillation during the periods of observation, which, in some instances, were as long as five or six years. Therefore, increased vagal activity, as manifested by delayed A-V conduction, is not an invariable precursor of auricular fibrillation. This is in accord with known physiologic facts, for it has been shown[5, 14, 15] that stimulation of the vagus nerve alone does not result in auricular fibrillation. Mines,[16] in his original work on circus movement in the heart, defined the two conditions necessary for the development of auricular fibrillation, i.e., prolonged conduction time and shortened refractory period of the auricular musculature. Lewis and his co-workers[17, 18, 19] and Andrus and Carter[4] have shown that stimulating the vagus shortens the refractory period of auricular muscle; it does not, however, slow the rate of conduction of impulses in the auricular myo-

cardium. Vagal action is an important factor, but by itself cannot therefore be expected to cause auricular fibrillation.

Nahum and Hoff[5] have advanced a hypothesis which attributes the development of auricular fibrillation in man to the simultaneous action of two factors, i.e., vagal activity and an E factor which acts in a manner as yet unknown. If certain other factors are already present, stimulation of the vagus nerve,[3, 4] or the use of drugs which act through the vagus, such as acetyl-B-methylcholine[5] or digitalis,[8, 9, 10, 13, 20-27] may cause auricular fibrillation. Nahum and Hoff suggested that in rheumatic heart disease the E factor may be the stretching of the auricular wall or the pathologic changes in the auricular myocardium itself.[28, 29] The relatively high incidence of auricular fibrillation in patients with prolonged P-R intervals who have been followed for a long time is to be ascribed to the fact that longer periods of observation increase the chances for the two factors responsible for the development of auricular fibrillation to occur simultaneously.

It might be argued that the increase in incidence of auricular fibrillation with longer periods of observation is not related directly to the presence of a prolonged P-R interval but may be due to the fact that both fibrillation and slowed A-V conduction time are independent expressions of the severer degrees of heart disease. Against this concept is the fact that auricular fibrillation in such patients may come and go, while the degree of damage to the heart remains constant.

Another indication of the significance of vagal activity in patients with a long P-R interval in whom auricular fibrillation develops is the finding, in four such patients in the present study, of idioventricular rhythm at the onset of the fibrillation, implying a high degree of A-V block. Of particular interest is the appearance of auricular fibrillation in one patient, here reported, following pulmonary infarction. Pulmonary embolism has been shown to cause stimulation of the vagus nerve.[30] Of interest, likewise, is the sequence of events in one patient in whom paroxysmal fibrillation was preceded by nodal rhythm and followed by prolongation of the P-R interval; nodal rhythm has been produced by vagal stimulation.[31]

The source of the vagal impulses which give rise to the changes in P-R interval and probably also to auricular fibrillation in rheumatic heart disease is not known. Bruenn[1] suggested that these impulses arise in the medulla; there are available at present no data concerning this possibility. It has, however, been shown that vagal impulses which affect the heart reflexly may arise from the root of the aorta,[32] the auricles or great veins,[33] and the lungs.[34, 35] That these structures are involved in rheumatic inflammatory processes is well known. Congestive failure, by raising the auricular or venous pressure and by causing pulmonary congestion, may also be a factor.

SUMMARY AND CONCLUSIONS

1. Fifty-five patients with prolonged P-R intervals associated with rheumatic heart disease were studied. Ten exhibited prolongation of the P-R interval for periods of a few days during the course of acute rheumatic fever. In forty-five cases prolongation of the P-R interval was persistent over a period ranging from one month to eight years. Approximately half the patients with persistent prolongation of the P-R interval due to rheumatic heart disease developed auricular fibrillation. More than three quarters of all patients with rheumatic heart disease who developed auricular fibrillation under observation previously showed a persistent prolongation of the P-R interval.

2. It has been shown by others that prolongation of the P-R interval in rheumatic heart disease is due to vagal activity; it appears that vagal activity is also a factor in the causation of auricular fibrillation in rheumatic cardiac patients.

3. Half of the rheumatic cardiac patients with persistent prolongation of the P-R interval do not develop auricular fibrillation. Therefore, vagal activity, by itself, is not an invariable precursor of auricular fibrillation. These facts are in accord with the hypothesis that the onset of auricular fibrillation is precipitated by the simultaneous action of two factors, i.e., vagal activity and the E factor of Nahum and Hoff.[5]

4. Rheumatic cardiac patients with a persistently prolonged P-R interval are much more likely to develop auricular fibrillation than those whose P-R interval is normal.

REFERENCES

1. Bruenn, H. G.: The Mechanism of Impaired Auriculo-Ventricular Conduction in Acute Rheumatic Fever, Am. Heart J. **13**: 413, 1937.
2. Cushny, A. R.: Irregularity of the Heart and Auricular Fibrillation, Am. J. M. Sc. **141**: 826, 1911.
3. Robinson, G. C.: The Influence of the Vagus Nerves on the Faradized Auricles in the Dog's Heart, J. Exper. Med. **17**: 429, 1913.
4. Andrus, E. C., and Carter, E. P.: The Refractory Period of the Normally-Beating Dog's Auricle; With a Note on the Occurrence of Auricular Fibrillation Following a Single Stimulus, J. Exper. Med. **51**: 357, 1930.
5. Nahum, L. H., and Hoff, H. E.: Auricular Fibrillation in Hyperthyroid Patients Produced by Acetyl-B-Methylcholine Chloride, With Observations on the Rôle of the Vagus and Some Exciting Agents in the Genesis of Auricular Fibrillation, J. A. M. A. **105**: 254, 1935.
6. Grant, R. T.: After Histories for Ten Years of a Thousand Men Suffering From Heart Disease. A Study in Prognosis, Heart **16**: 275, 1933.
7. DeGraff, A. C., and Lingg, C.: The Course of Rheumatic Heart Disease in Adults. III. The Influence of Auricular Fibrillation on the Course of Rheumatic Heart Disease, Am. Heart J. **10**: 630, 1935.
8. Mackenzie, J.: The Schorstein Lectures on Auricular Fibrillation, Brit. M. J. **2**: 869, 1911.
9. Reid, W. D.: Some Toxic Effects of Digitalis, J. A. M. A. **81**: 435, 1923.
10. Schwartz, S. P.: Digitalis Studies in Children With Heart Disease. III. Auricular Fibrillation in Children With an Early Toxic Digitalis Manifestation, Am. J. Dis. Child. **39**: 549, 1930.
11. Cookson, H.: The Aetiology and Prognosis of Auricular Fibrillation, Quart. J. Med. **23**: 309, 1930.

12. Orgain, E. S., Wolff, L., and White, P. D.: Uncomplicated Auricular Fibrillation and Auricular Flutter. Frequent Occurrence and Good Prognosis in Patients Without Other Evidence of Cardiac Disease, Arch. Int. Med. **57**: 493, 1936.
13. Tung, C. L.: Transient Auricular Fibrillation as a Toxic Manifestation of Digitalis, AM. HEART J. **12**: 272, 1936.
14. Starr, I., Jr., Elsom, K. A., Reisinger, J. A., and Richards, A. N.: Acetyl-B-Methylcholin. I. The Action on Normal Persons With a Note on the Action of the Ethyl Ether of B-Methylcholin, Am. J. M. Sc. **186**: 313, 1933.
15. Dameshek, W., Loman, J., and Myerson, A.: Human Autonomic Pharmacology. VII. The Effect on the Normal Cardiovascular System of Acetyl-Beta-Methylcholine Chloride, Atropine, Prostigmin, Benzedrine—With Especial Reference to the Electrocardiogram, Am. J. M. Sc. **195**: 88, 1938.
16. Mines, G. R.: On Dynamic Equilibrium in the Heart, J. Physiol. **46**: 349, 1913.
17. Lewis, T.: The Law of Cardiac Muscle With Special Reference to Conduction in the Mammalian Heart, Quart. J. Med. **14**: 339, 1921.
18. Lewis, T., Drury, A. N., and Bulger, H. A.: Observations Upon Flutter and Fibrillation. VI. The Refractory Period and Rate of Propagation in the Auricle: Their Relation to Block in the Auricular Walls and to Flutter, Heart **8**: 83, 1921.
19. Lewis, T., and Master, A. M.: Observations Upon Conduction in the Mammalian Heart. A-V Conduction, Heart **12**: 209, 1925.
20. Cushny, A. R.: The Therapeutics of Digitalis and Its Allies, Am. J. M. Sc. **141**: 469, 1911.
21. Mackenzie, J.: Digitalis, Heart **2**: 273, 1911.
22. Nadel, V.: Ein Fall von Flimmerarhythmie im Kindersalter. Mitt. d. Gesellsch. f. inn. Med. u. Kinderh. in Wien. **12**: 210, 1913.
23. Danielopolu, D.: Arythmie complète chez l'homme, provoquée par la digitale; rôle du systeme modérateur, Compt. rend. Soc. de biol. **79**: 97, 1916.
24. Resnik, W. H.: Transient Auricular Fibrillation Following Digitalis Therapy, With Observations Upon the Reaction to Atropine, J. Clin. Investigation **1**: 181, 1924.
25. Schwartz, S. P.: The Action of Digitalis in Complete Heart Block. Its Toxic Influence on the Idioventricular Rate and Rhythm, AM. HEART J. **4**: 408, 1929.
26. Mc Eachern, D., and Baker, B. M., Jr.: Auricular Fibrillation. Its Etiology, Age Incidence and Production by Digitalis Therapy, Am. J. M. Sc. **183**: 35, 1932.
27. Jezer, A., and Schwartz, S. P.: Auricular Fibrillation as an Early Toxic Digitalis Manifestation; Further Observations on This Drug in Children With Congestive Heart Failure, J. Pediat. **5**: 811, 1934.
28. De la Chapelle, C. E., Graef, I., and Rottino, A.: Studies in Rheumatic Heart Disease. An Analysis of 119 Hearts With Special Reference to the Relationship of Auricular Fibrillation to Mitral Valvular Deformity and Certain Rheumatic Tissue Changes, AM. HEART J. **10**: 62, 1934.
29. Gross, L.: Lesions of the Left Auricle in Rheumatic Fever, Am. J. Path. **11**: 711, 1935.
30. Binger, C. A. L., Brow, G. R., and Branch, A.: Experimental Studies on Rapid Breathing. I. Tachypnea, Independent of Anoxemia, Resulting From Multiple Emboli in the Pulmonary Arterioles and Capillaries, J. Clin. Investigation **1**: 127, 1924.
31. Meek, W. J., and Eyster, J. A. E.: Experiments on the Origin and Propagation of the Impulse in the Heart, Heart **5**: 227, 1914.
32. Eyster, J. A. E., and Hooker, D. R.: Direct and Reflex Response of the Cardio-Inhibitory Centre to Increased Blood Pressure, Am. J. Physiol. **21**: 373, 1908.
33. Bainbridge, F. A.: The Influence of Venous Filling Upon the Rate of the Heart, J. Physiol. **50**: 65, 1915.
34. Churchill, E. D., and Cope, O.: The Rapid Shallow Breathing Resulting From Pulmonary Congestion and Edema, J. Exper. Med. **49**: 531, 1929.
35. Schwiegk, H.: Der Lungenentlastungsreflex, Pflüger's Arch. f. d. ges. Physiol. **236**: 206, 1935.

ROENTGENKYMOGRAPHIC STUDIES OF MYOCARDIAL INFARCTION*

RICHARD GUBNER, M.D., AND J. HAMILTON CRAWFORD, M.D.†
BROOKLYN, N. Y.

SINCE the classical description by Herrick, in 1912,[1] coronary thrombosis has become a well-recognized clinical entity. Frequently, however, the history is atypical and physical findings are minimal, while on occasion the cardinal symptom of pain may be entirely absent. In such cases additional diagnostic methods are necessary.

The electrocardiogram has proved to be an invaluable aid in the diagnosis of coronary thrombosis and is frequently the only means available for its recognition. The first description of electrocardiographic changes due to interference with coronary blood supply was given by Smith,[2] who ligated branches of the coronary arteries in dogs. Following these observations and those of Herrick[3] and of Pardee[4] on coronary thrombosis in man, the investigations of Parkinson and Bedford[5] and of Barnes and Whitten[6] established the value of the electrocardiogram in the diagnosis of coronary thrombosis, and indicated further that the site of the infarct could be localized by the electrocardiographic pattern. This work was soon corroborated by Bell and Pardee[7] and by Levine,[8] and was confirmed experimentally by Barnes and Mann,[9] Crawford, Roberts, Abramson, and Cardwell,[10] and by Haney, Borman, and Meek.[11]

More recently, the electrocardiographic diagnosis and localization of myocardial infarction have been made still more precise by the employment of the precordial lead, as suggested by Wolferth and Wood,[12] and it is now well recognized that in many cases infarcts are demonstrable electrocardiographically only in the precordial lead.

In addition to the problem of diagnosis in acute coronary thrombosis, the appraisal of the extent of myocardial damage in patients who present a history suggestive of a previous coronary thrombosis, or of angina pectoris, is important. Physical findings are very often meager, and while the electrocardiogram may indicate myocardial disease, it does not show the amount of involvement; in fact, one may obtain a normal electrocardiogram when extensive damage is present. In a series of eighty-six cases of coronary artery disease studied post mortem by Willius and Brown,[13] thirty-four of the patients, or 40 per cent, presented no clinical evidence of cardiac disease. Any additional methods which throw further light on the diagnosis of myocardial disease are, therefore, to be welcomed.

*Presented before the American Society for Clinical Investigation, May, 1938.

†From the Department of Medicine, Long Island College of Medicine and the Kings County Hospital.

Received for publication Dec. 3, 1938.

Ordinary roentgenologic examination is of little value in coronary artery disease, except to indicate cardiac enlargement and occasionally to demonstrate an aneurysm of the left ventricle secondary to myocardial infarction. The results of fluoroscopic examination, although sometimes suggestive, are far from definite.

Roentgenkymography, in contrast to plain roentgenologic examination, is a method for investigating function, rather than structure, by recording the movements of the heart throughout the cardiac cycle. In the hope that this technique might contribute more to the recognition of myocardial damage than the usual roentgenologic examination, forty-five patients with coronary thrombosis were studied with the kymograph. An attempt was made to localize and determine the extent of the infarct by changes in the contractility of the different parts of the heart as revealed in the movement phenomena.

METHOD AND INTERPRETATION

The technique employed is the same as has been described in detail by Stumpf[15] and Hirsch.[16] Briefly, the roentgenkymogram is obtained by interposing between the subject and the film a cassette containing a lead grid with multiple, thin, horizontal slits about 0.4 mm. wide. The only parts of the heart shadow recorded on the film, therefore, are those thin segments opposite the slits, all other rays being blocked by the impervious lead grid. If the film is moved downward during a continuous exposure, the inthrusts and outthrusts of the points of the cardiac contour exposed will be recorded on the moving film in the form of a wave, the waves being repeated with each cardiac cycle. The slits are spaced 12 mm. apart, and the film is moved just short of the distance between two slits to prevent overlapping of the waves. The movement of points of the cardiac shadow at 12 mm. intervals is thereby obtained. With an exposure of one second, one to two complete cardiac cycles are generally recorded, depending on the heart rate. When the heart rate is slow, an exposure of one and one-half to two seconds is preferable. Since the film moves down during the exposure, the time ordinate is upward. Fig. 1 illustrates the kymogram of a normal subject.

With this method, therefore, one can visualize the movement of points all along the left ventricular contour at 12 mm. intervals. Exposures taken in the posteroanterior and in the slight and full left oblique positions (about 25° and 60 to 70°, Figs. 2*A*, *B*, *C*) enable one to obtain a record of the contraction of the anterolateral wall, of a large part of the posterior wall of the left ventricle, and of the right ventricle in addition.

The waves of each chamber are characteristic, and are readily susceptible of physiologic interpretation.[17] The aortic and pulmonary arterial waves are identical with carotid sphygmograms. The right auricular waves are multiple, and correspond to the a, c, and v waves of

the jugular pulse. The ventricular waves resemble ventricular volume curves. Johnson[18] has found a close correspondence between the amplitude of the ventricular wave and the stroke volume, as determined by the dye method. However, the ventricular wave is not a true volume

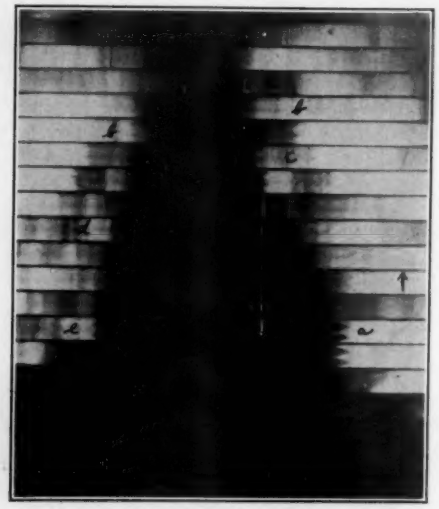
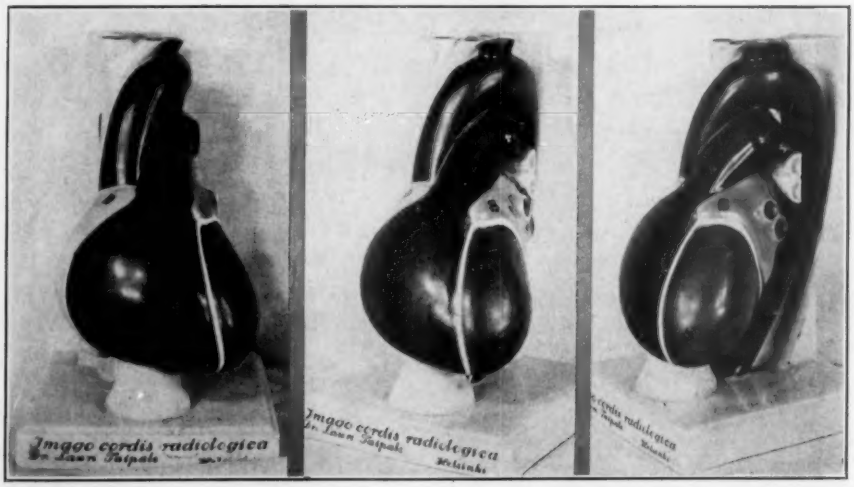


Fig. 1.—Normal kymogram.



A. *B.* *C.*

Fig. 2.—Anatomic relationships of the various chambers in the different views in which kymograms were taken, illustrating particularly the area of the left ventricle visualized. *A*, Posteroanterior; *B*, slight left oblique; *C*, full left oblique.

record for the following reasons: (1) The kymogram is taken at a distance of 3 feet, and there is therefore some magnification. (2) Due to the oblique position of the heart border on the left side, its movements, recorded through a horizontal slit, are distorted. This may, however, be easily corrected for and the true amplitude obtained (Fig. 3). (3)

In addition to the predominant contractile movement of the ventricle, there are other movements as well, i.e., elevation of the apex and positional changes of the heart as a whole.

The movement of the apex is particularly variable, and is reduced in cardiac decompensation because of the impaired contraction of the ventricle as a whole, with a consequent diminution or loss of the normal upward apical thrust. Furthermore, as Kirch[19] has emphasized, the apex is the most labile portion of the ventricle, and atrophy and thinning of the apex with loss of contractility occur in cardiac enlargement with heart failure of whatever cause. Esser[20] has clearly shown that reverse pulsations may occur at the apex when the heart is greatly dilated. For this reason great caution must be observed in interpreting diminution or absence of pulsations in this region as indicative of infarction. The great majority of the hearts included in this series, however, were not markedly enlarged, so that this criticism does not invalidate the findings. The only condition we have encountered in a heart of about normal size, other than coronary thrombosis, in which there was no visible contraction of the left ventricle, was constrictive pericarditis (diagnosis confirmed at operation).

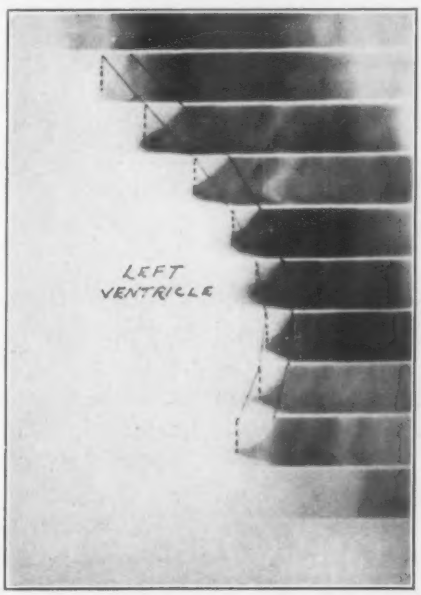


Fig. 3.—Outline of left ventricle in systole and diastole. Since the contour of the heart is not perpendicular to the slit at all points, in order to estimate the amplitude of contraction the crests and troughs of the waves must be brought to the same horizontal level.

Recognizing the limitations of the ventricular wave as an index of volume changes, the amplitude of the waves, nevertheless, reflects, with fair accuracy, the contraction of individual portions of the ventricle, and the failure of localized areas to contract becomes significant. When

there is definite reversal of the waves in a certain region, as was the case in a large percentage of the present series, the interpretation that this is the site of infarction seems valid. Similarly, when there is a sudden change from active to practically absent pulsation, one appears justified in assuming that the contractility of this region is actually markedly impaired; indeed, at times one observes active contraction both above and below the area of absent pulsation. In an extensive experience with kymography in various types of heart disease other than coronary thrombosis, we have observed a reversal of pulsation only once, in a case of rheumatic mitral disease. The heart was only moderately enlarged, and the reason for the reverse pulsation in the apical region is not clear. The most likely causes would seem to be alteration of the movement of the heart as a whole, or impaired contractility due to extensive damage in this region.

Most of the records were taken during convalescence, as soon as the patient was able to get out of bed. It has thus far not been possible to check the findings by post-mortem examination, since none of the patients has yet come to autopsy. However, the kymographic findings were compared with the electrocardiographic localization, precordial leads being taken, in addition to the standard leads, in all cases. Levine, Lowman, and Wissing[14] have recently reported a series of 140 cases which were studied fluoroscopically. In some of the cases posteroanterior kymograms were made, but no oblique views were taken. The radiologic diagnosis of coronary disease was confirmed electrocardiographically in 75 per cent of the cases. No statement was made concerning localization of the infarcts. In twelve cases in which autopsy was performed the electrocardiographic diagnosis was confirmed in eleven and the roentgenologic in ten.

RESULTS

Table I summarizes the roentgenkymographic and electrocardiographic findings in forty-five cases of coronary thrombosis.

In the first two cases listed in the table there could be no doubt about the nature of the anatomic lesion. A diagnosis of ventricular aneurysm was made clinically and confirmed by ordinary roentgenologic and kymographic examinations in both of these cases.

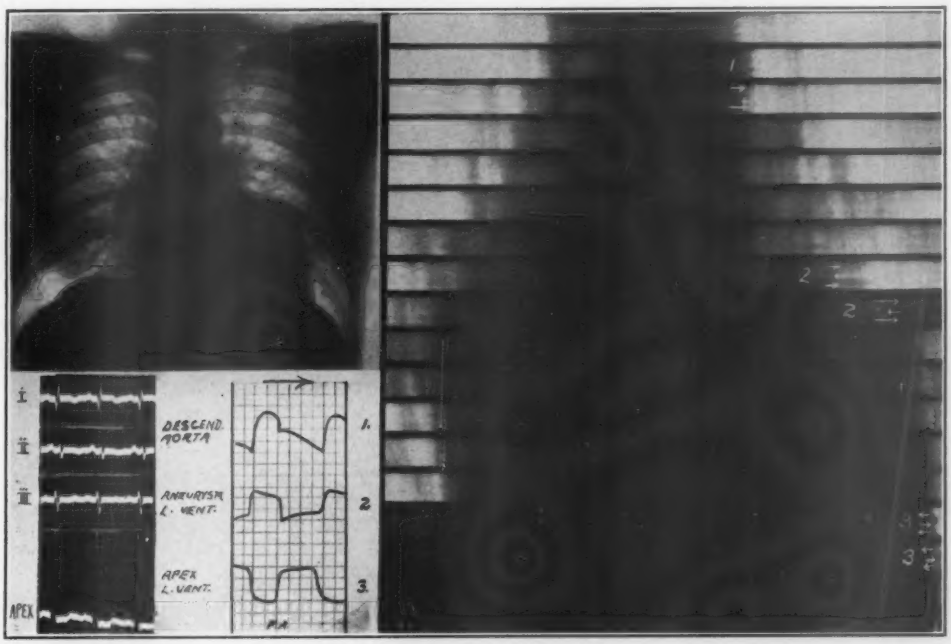
Fig. 4, *A* to *C*, shows the roentgenogram, the roentgenkymogram, a graphic correlation of the waves on a time axis, and the electrocardiogram, in Case 1. This patient had had four attacks of coronary thrombosis, and had a distinct thrust over a wide area of the precordium. The diagnosis of ventricular aneurysm was confirmed roentgenologically (Fig. 4*A*). The kymogram (Fig. 4*C*) shows a complete reversal of contraction over the aneurysmal area, i.e., while the rest of the ventricle contracts this segment distends as a passive sac, collapsing at the end of systole when the fall of intraventricular pressure relieves the tension on the aneurysmal area. This reverse movement is clearly shown in the graphic correlation of the waves in Fig. 4*B*.

The forty-five cases may be divided into five groups (Table II).

Group 1.—Group 1 comprises 25 cases in which the kymographic and electrocardiographic localization of the infarct corresponded. Twenty of the infarcts were of the anterior wall, 5 of the posterior wall.

Fig. 5, *A* to *D*, shows the kymograms of a patient whose electrocardiographic changes indicated an anterior wall infarct (Fig. 5*A*). A reverse movement is seen over the lower half of the ventricle in the posteroanterior view (Fig. 5*B*). The movements of the lateral and posterior ventricular walls in the slight and full left oblique positions are entirely normal (Figs. 5*C* and 5*D*).

A.



B. *C.*

Fig. 4.—Ventricular aneurysm. *A*, Posteroanterior view; *B*, electrocardiogram showing Q_1 T_1 pattern (the precordial leads were taken with the right arm electrode at apex and left leg electrode on left leg, original method) and correlation of kymographic waves on a time axis; *C*, posteroanterior kymogram. Reverse pulsation over aneurysmal area.

Fig. 6, *A* to *C*, on the other hand, shows the kymograms of a patient whose electrocardiographic changes indicated a posterior wall infarct (Fig. 6*A*). The movement of the anterior wall of the left ventricle, as seen in the posteroanterior kymogram, is normal except for diminished pulsation of the midsection of the left ventricle. An inthrust instead of the usual filling at the onset of diastole suggests an abnormality of contraction in this region (Fig. 6*B*). In the slight oblique view there is complete reversal of ventricular movement in the midsection of the left ventricle at the same level at which there was a suggestion of ab-

normality in the posteroanterior view (Fig. 6*C*). The kymogram thus indicates an infarct of the midsection of the posterolateral wall of the left ventricle.

Group 2.—In the 6 cases of Group 2 the kymogram showed involvement of both anterior and posterior walls. The electrocardiographic

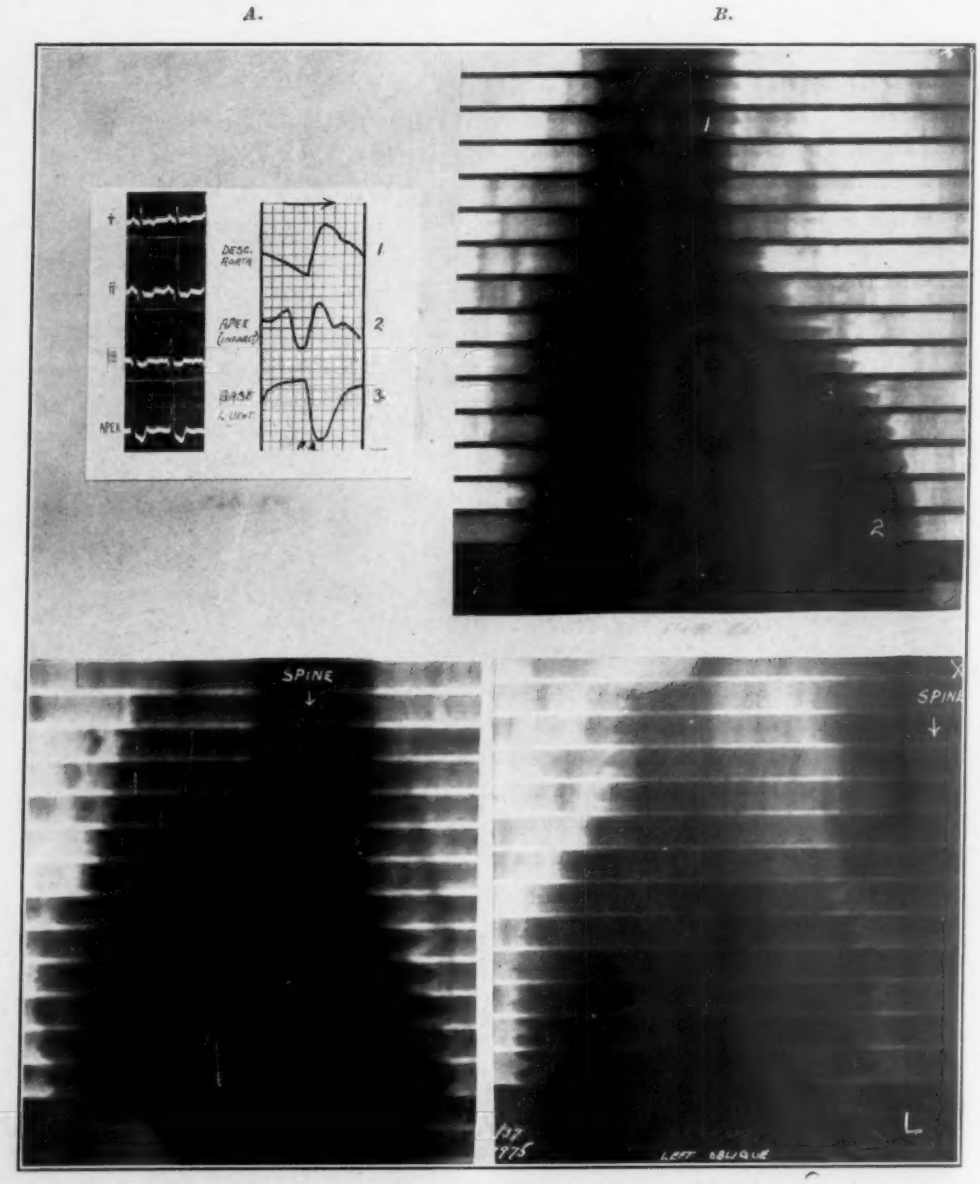
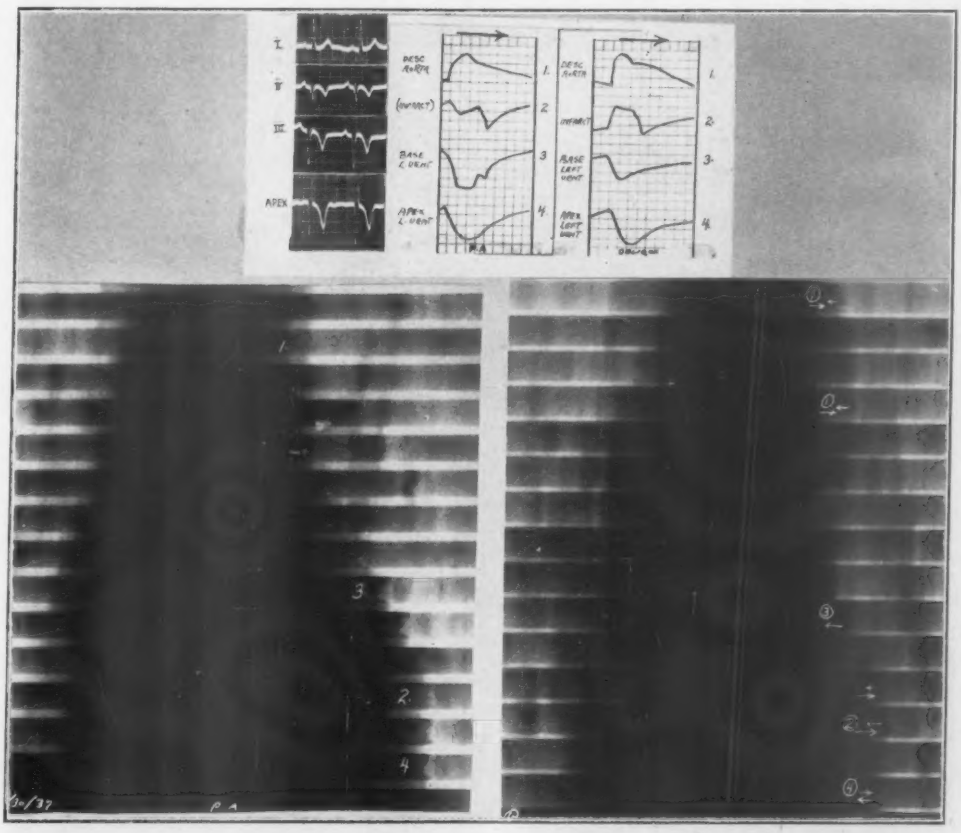


Fig. 5.—Anterior wall infarction. *A*, Electrocardiogram showing Q_1 T_1 pattern and correlation of kymographic waves on a time axis; *B*, posteroanterior kymogram showing reversal of waves at apex; *C*, slight left oblique—normal waves; *D*, full left oblique—normal waves.

localization was posterior wall in 4 cases and anterior wall in 2 cases. Extensive areas of infarction were revealed by the kymogram. Fig. 7, *B* and *C*, illustrates an area of infarction in the midsection anteriorly and posteriorly. The posteroanterior view shows reverse movement of four segments (Fig. 7*B*). In the slight left oblique view there is also reverse movement at the same level (Fig. 7*C*). The electrocardiographic changes in this case indicated involvement of the posterior wall (Fig. 7*A*).

A.



B. *C.*

Fig. 6.—Posterior wall infarction. *A*, Electrocardiogram showing Q_3 T_3 pattern and correlation of kymographic waves on a time axis; *B*, posteroanterior kymogram, impaired contractions at midsection; *C*, slight left oblique, reversal of waves in midsection.

Group 3.—Five cases in which the kymographic and electrocardiographic findings did not agree comprise this group. The electrocardiogram indicated posterior wall infarction in 4 cases and anterior wall infarction in 1 case. The kymograms showed an infarct of the anterior wall in one case in which the electrocardiogram suggested posterior wall infarction, and nothing abnormal in the other 4 cases. Possibly the

site of infarction was not registered in the kymogram because the area involved was too small or not included in the part recorded. There is a small area close to the septum, in the region of the diaphragm, which cannot be seen in the views included in this study. It is apparent that there is better correspondence with anterior than with posterior wall infarcts. This is probably due to the easier visualization of the anterior wall in the kymogram.

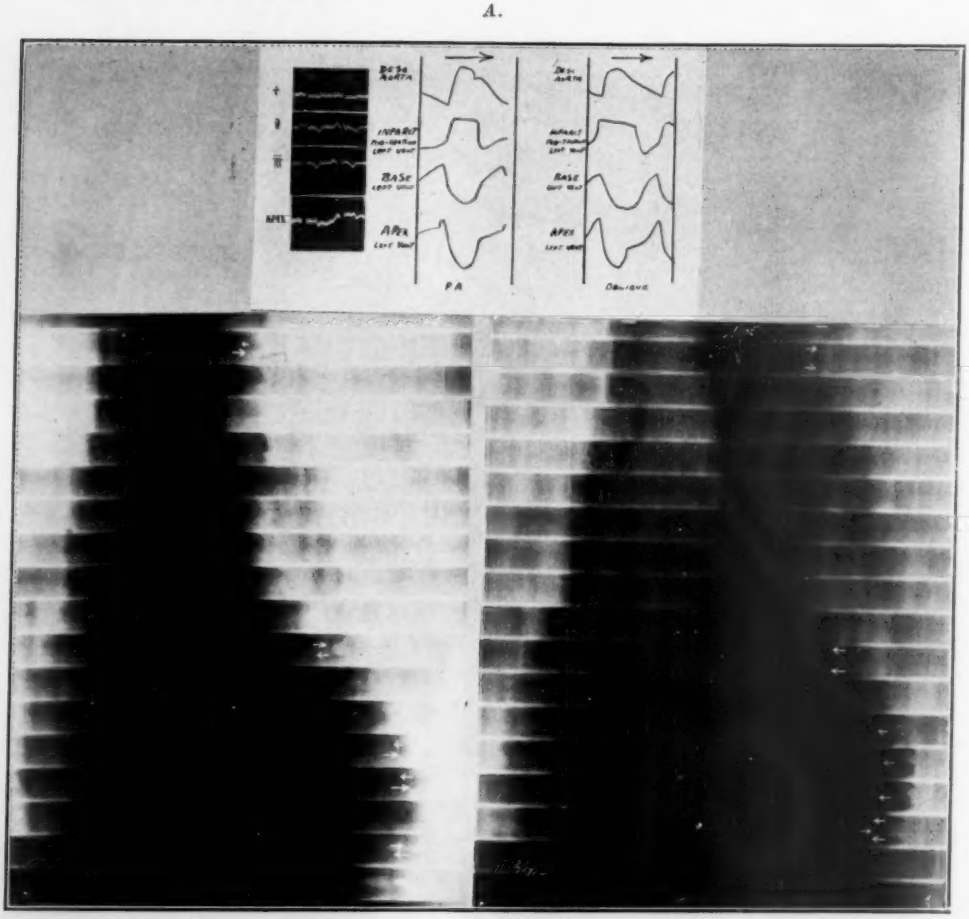


Fig. 7.—Anterior and posterior wall infarction. *A*, Electrocardiogram showing changes in all leads, suggestive more of posterior wall involvement, and correlation of kymographic waves on a time axis; *B*, posteroanterior, reversal of waves in midsection; *C*, slight left oblique, reversal of waves in midsection.

Group 4.—This comprised 3 cases in which no localization was possible electrocardiographically because of bundle branch block, except that one could say that the septum was involved. The kymogram showed an area of infarction of the anterior ventricular wall in two cases, and of both anterior and posterior walls in one case.

TABLE I

CASE		AGE	NUMBER AND SEVERITY OF ATTACKS	ELECTROCARDIOGRAPHIC LOCALIZATION	KYMOGRAPHIC LOCALIZATION
1.	F. A.	55	4th attack, ventricular aneurysm	Anterior wall	Anterior wall, upper half (reverse movement)
2.	M. M.	59	1st attack ventricular aneurysm	Posterior wall	Anterior wall, and posterior wall, lower third (reverse movement in posteroanterior—absent movement in oblique)
3.	B. W.	57	1st attack, severe, heart failure	Anterior wall	Anterior wall Aneurysmal dilatation of midsection with absent to slightly reverse movement
4.	C. C.	52	2nd attack	Anterior wall	Anterior wall, lower half (absent movement)
5.	M. H.	56	4th attack	Anterior wall	Anterior wall, apex (reverse movement)
6.	A. B.	69	3rd attack, severe	Anterior wall (intermittent auricular flutter and fibrillation)	Anterior wall near apex (diminished to absent movement)
7.	G. S.	38	1st attack	Anterior wall	Anterior wall, apical region extending to posterior wall in lowermost segments (reverse movement in posteroanterior, absent movement in obliques)
8.	J. S.	44	1st attack	Anterior wall	Anterior wall, upper half (reverse movement)
9.	W. B.	58	1st attack	Anterior wall	Anterior wall, lower half extending to posterior wall in lowest segments (absent movement)
10.	J. S.	57	1st attack	Anterior wall	Anterior wall, upper third (reverse movement)
11.	S. W.	60	1st attack	Anterior wall	Anterior wall, apex (greatly diminished movement)
12.	W. M.	43	1st attack	Anterior wall	Anterior wall apex (practically absent movement)
13.	A. R.	72	2nd attack	Probable anterior wall	Anterior wall, upper half (reverse movement)
14.	M. K.	44	4th attack	Anterior wall	Anterior wall, entire (absent to slightly reverse movement)
15.	M. J.	40	2nd attack	Anterior wall	Anterior wall, lower half (reverse movement)
16.	C. W.	49	1st attack	Anterior wall	Anterior wall, apical region (greatly diminished movement)
17.	M. M.	53	1st attack	Anterior wall	Anterior wall, midsection (diminished movement)
18.	J. C.	55	1st attack	Anterior wall	Anterior wall, lower 2/3 (reverse movement)
19.	L. G.	36	1st attack	Anterior wall	Anterior wall, upper half (reverse movement)

TABLE I (CONTINUED)

CASE		AGE	NUMBER AND SEVERITY OF ATTACKS	ELECTROCARDIOGRAPHIC LOCALIZATION	KYMOGRAPHIC LOCALIZATION
20.	E. S.	76	?	Anterior wall	Anterior wall, lower 2/3 (reverse movement)
21.	M. M.	42	1st attack, embolization to right leg	Probable posterior wall	Posterior wall, upper 2/3 Anterior wall, upper 1/4 (reverse movement)
22.	P. B.	62	1st attack	Posterior wall	Posterior wall, midsection (reverse movement)
23.	S. G.	63	1st attack	Posterior wall	Posterior wall, midsection (reverse movement)
24.	A. A.	55	1st attack	Posterior wall	Posterior wall, upper 2/3 (reverse movement)
25.	A. Z.	46	1st attack	Anterior wall	Lateral wall, lower half (absent movement)
26.	N. S.	63	1st attack	Posterior wall	Posterior wall, midsection (partial reverse movement)
27.	J. S.	70	1st attack, angina 13 yr.	Posterior wall	Anterior wall, lower half Posterior wall, lowest segments (absent movement in posteroanterior, reverse movement in oblique)
28.	H. S.	50	1st attack, severe	Anterior wall	Anterior wall, lower half Posterior wall, lower third (reverse movement)
29.	C. S.	49	1st attack	Posterior wall	Anterior wall, apical region Posterior wall, lower 1/4 (Reverse movement in posteroanterior, absent movement in 1/2 oblique, partial reverse movement in full oblique)
30.	M. S.	52	1st attack	Posterior wall	Anterior wall, midsection Posterior wall, midsection (reverse movement)
31.	W. W.	61	1st attack	Anterior wall Intraventricular conduction disturbance	Anterior wall, midsection Posterior wall, midsection (diminished movement)
32.	G. O.	43	1st attack 3 years ago. Intermittent decompensation since	Right bundle branch block	Anterior wall, lower half (reverse movement) Posterior wall—not clear
33.	A. S.	66	1st attack	Possible septal infarct Periods of nodal rhythm and of left bundle branch block	Anterior wall, apex (greatly diminished to absent movement)
34.	L. S.	64	1st attack, severe	Left bundle branch block	Anterior wall—segment above apex Posterior wall—lower half (reverse movement)
35.	J. S.	52	1st attack	Posterior wall	Anterior wall—apical region (absent movement)

TABLE I (CONTINUED)

CASE		AGE	NUMBER AND SEVERITY OF ATTACKS	ELECTROCARDIOGRAPHIC LOCALIZATION	KYMOGRAPHIC LOCALIZATION
36.	U. T.	40	1st attack	Posterior wall	Normal
37.	M. Y.	75	1st attack	Posterior wall	Normal
38.	M. B.	45	1st attack	Anterior wall	Normal
39.	M. D.	46	1st attack	Posterior wall	Normal
40.	J. M.	52	Angina 6 yr. Decompensation 2 yr.	Myocardial damage	Anterior wall, lower ⅔ (reverse movement)
41.	H. R.	53	Severe angina 5 yr.	Myocardial damage Extensive changes	Anterior wall, lower ½ Lateral wall, lower ⅔ Posterior wall, lower ½ (reverse movement)
42.	W. I.	73	Angina 10 yr. Impaired cardiac reserve 7 yr.	Normal, T_4 diphasic	Anterior wall, lower ½ Lateral wall, normal Posterior wall, midsection (reverse movement)
43.	W. W.	40	Heart failure, hypertensive	Myocardial damage	Anterior wall, lower ½ (reverse movement)
44.	B. T.	64	2nd attack	Myocardial damage	Anterior wall—apex Posterior wall—midsection (slightly reverse movement)
45.	W. N.	41	Hypertension aortic aneurysm	Marked myocardial changes	Anterior wall—midsection Posterior wall—midsection (partial reverse)

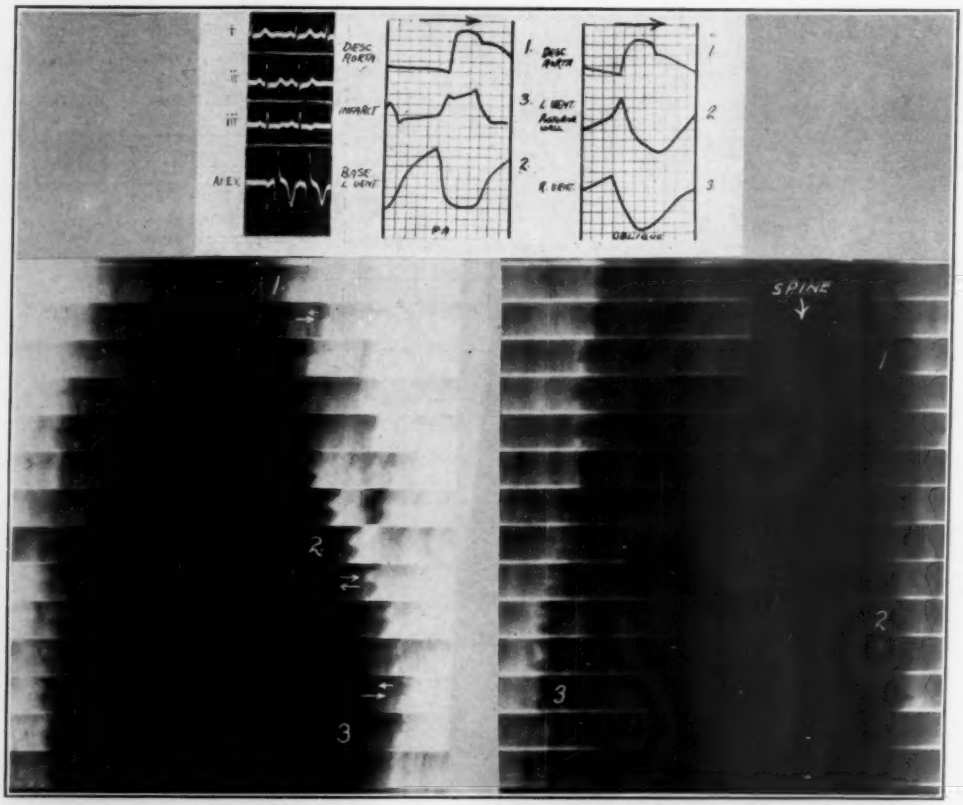
TABLE II

Group 1:	*Agreement in Localization*		*25 Cases*
	Anterior wall	20 Cases	
	Posterior wall	5 Cases	
Group 2:	*Partial Agreement*		*6 Cases*
EKG:	Posterior wall	4 Cases	
	Anterior wall	2 Cases	
Kymogram:	Anterior and posterior walls—in all	6 Cases	
Group 3:	*Disagreement*		*5 Cases*
EKG:	Posterior wall	4 Cases	
	Anterior wall	1 Case	
Kymogram:	Anterior wall	1 Case	
	Normal	4 Cases	
Group 4:	*No Localization Possible From EKG*		*3 Cases*
EKG:	Bundle branch block	3 Cases	
Kymogram:	Anterior wall	2 Cases	
	Posterior wall	1 Case	
Group 5:	*Coronary Disease*		*6 Cases*
	(No Definite Infarct Clinically or in EKG)		
EKG:	Myocardial damage	5 Cases	
	Normal	1 Case	
Kymogram:	Anterior wall	3 Cases	
	Anterior and posterior walls	3 Cases	
Total			*45 Cases*

Group 5.—A group which is of particular interest comprises 6 cases of coronary artery disease in which a diagnosis of myocardial infarction

could not be made clinically or from the electrocardiogram. In all of these the kymogram revealed an area of infarction; in 3, the anterior wall was involved, and in 3 both anterior and posterior walls. Fig. 8, *B* and *C*, shows the kymograms in this type of case. There is a definite reversal of movement of the lower half of the anterior wall of the left ventricle, with normal contraction over the entire ventricle in the oblique view. The patient was a man 73 years of age with a long-standing history of angina pectoris and impaired cardiac reserve. He gave no history of an attack suggesting coronary artery thrombosis. There was no

A.



B. *C.*

Fig. 8.—Anterior wall infarction in patient, age 73 years, with normal electrocardiogram. *A*, Normal electrocardiogram and correlation of kymographic waves on a time axis; *B*, posteroanterior, reversal of waves at apex; *C*, left oblique, normal waves.

cardiac enlargement. The electrocardiogram (Fig. 8*A*) gave no hint of myocardial infarction. Levine and Levine[21] studied a group of 44 patients with angina pectoris who were subsequently autopsied, and found that "myocardial infarction is not uncommon in angina pectoris when there is no clinical evidence of a previous coronary thrombosis."

Not infrequently, some months after an acute attack of coronary thrombosis the electrocardiogram may return practically to normal. Under these circumstances an area of myocardial infarction may still be detected in the kymogram. The first of the two electrocardiograms

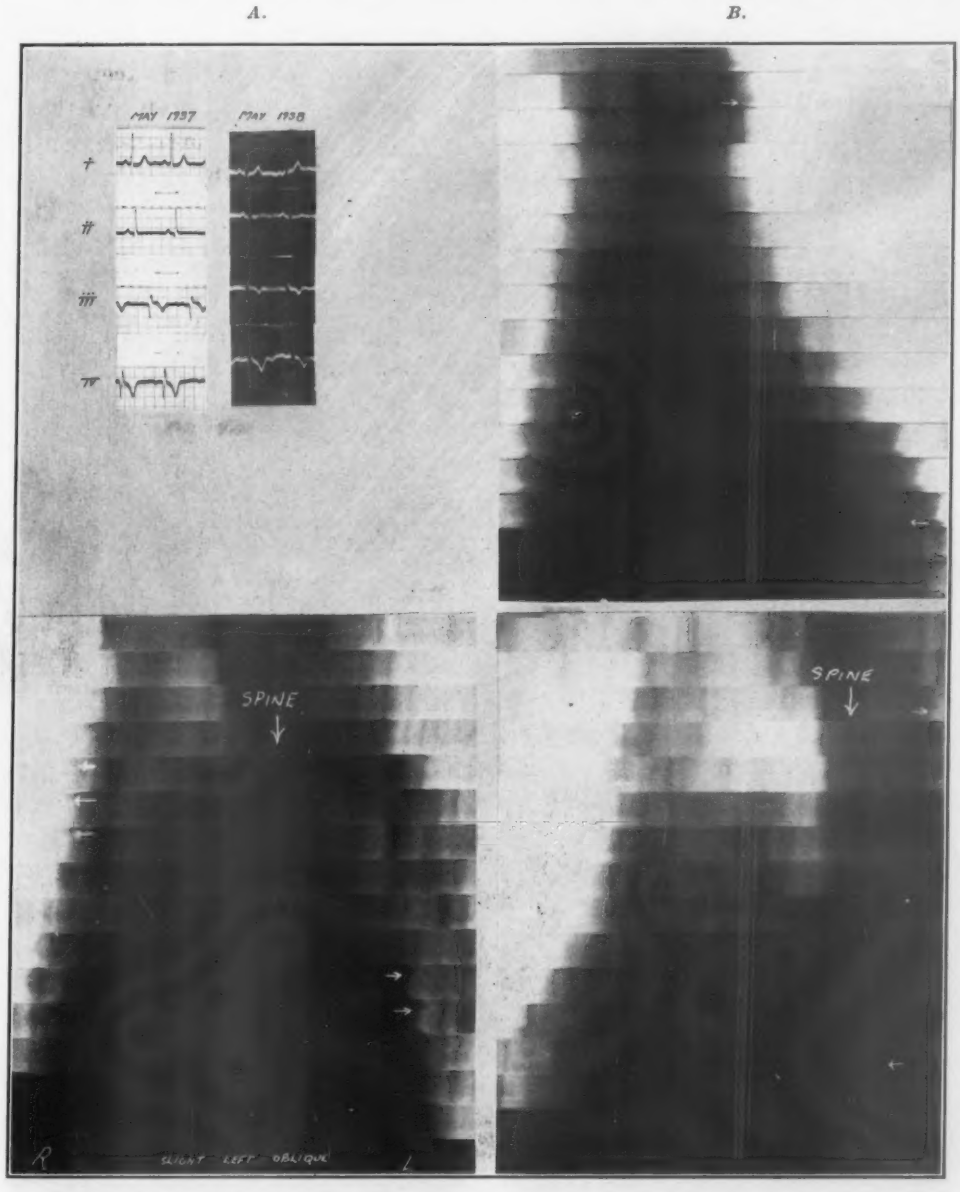


Fig. 9.—Posterior wall infarction in patient who showed Q_3 T_3 electrocardiographic pattern and in whom a year later the electrocardiogram reverted sufficiently toward normal to cause confusion if this had been the only record available. *A*, Electrocardiograms at intervals of one year; *B*, posteroanterior, normal waves; *C*, slight left oblique, reversal of waves in midsection; *D*, full left oblique, normal waves.

in Fig. 9*A*, taken during the acute attack of coronary thrombosis, was of the Q_3 T_3 type indicative of posterior wall infarction. The second electrocardiogram, taken one year later, shows little abnormality except for the deep Q wave in Lead III. The kymograms (Fig. 9, *B* to *D*), taken at the time of the second electrocardiogram, show normal movement of the left ventricle in the posteroanterior and in the full left oblique positions (Fig. 9, *B* and *D*). In the slight left oblique view, however, there is a distinct reversal of pulsation of some segments, indicating infarction of the lateral wall of the left ventricle (Fig. 9*C*).

DISCUSSION

An experimental basis for the kymographic study of myocardial infarction is afforded by the work of Tennant and Wiggers.[22] These investigators studied, by means of the myocardiograph, the effect of occluding branches of the coronary arteries in the dog on the contractility of the area supplied. They found that almost immediately after occluding a particular vessel the region involved ceased to contract, and reversal of movements took place. While the rest of the ventricle contracted normally during systole, the ischemic area was distended by the raised intraventricular systolic pressure.

As seen in the cases illustrated, varying types of movement are found in areas of infarction. Most frequently, reversal, partial reversal, or absence of movement is observed. Occasionally, multiple, small, bizarre waves are present. It is difficult to explain why in one case the pulsations are absent and in another reverse pulsations occur. Both types may even occur in different segments in the same patient. A possible explanation lies in the varying degree of endocardial lamination of the infarct with mural thrombi; such lamination occurs in over one-half of all cases of coronary thrombosis, according to the observations of Applebaum and Nicolson.[23] In those cases in which the pulsations are absent there may be dense mural thrombi, whereas reverse pulsations are more likely to occur when, because there is no mural thrombus, the thinned area of infarction can distend with the systolic rise of intraventricular pressure. Indirect evidence for this was afforded in a case of aortic aneurysm in which there was no aortic pulsation in the kymogram. At post-mortem examination a densely laminated clot was found in the aneurysmal sac.

A frequent finding over normal as well as abnormal regions of the ventricle in coronary thrombosis is the disappearance of a small serration superimposed on the ventricular wave. This normally occurs at the onset of systole and is synchronous with the first heart sound.[15] It probably reflects a positional change of the heart with the sudden rise of intraventricular pressure during the isometric phase of ventricular systole. Its disappearance in coronary thrombosis, as well as

in other kinds of myocardial disease, is possibly due to a less abrupt rise of intraventricular pressure.

SUMMARY

Forty-five cases of myocardial infarction were studied with the multiple-slit, moving-film kymograph. Exposures were made in the postero-anterior and two left oblique positions, thus visualizing the movements of the anterior and posterolateral walls of the left ventricle.

The technique is considered briefly and the physiologic interpretation of the ventricular wave as an index of ventricular volume changes is discussed.

The changes observed varied from reversal of movement to absence of pulsation in the infarcted area, and correspond to those recorded by Tennant and Wiggers with the myocardiograph in experimental myocardial infarction in dogs. A comparison was made between kymographic and electrocardiographic localizations in 45 cases. In 41 of the 45 cases there were definite kymographic changes. In 25 the electrocardiographic and kymographic localizations corresponded exactly. In 6 cases the kymogram indicated involvement of both anterior and posterior walls, whereas the electrocardiogram suggested infarction of one or the other. In 3 cases in which no electrocardiographic evidence of damage to the ventricular wall could be obtained because bundle branch block was present, the kymogram showed an area of infarction. In 1 case the electrocardiographic and kymographic localizations disagreed, and in 4 cases with definite coronary thrombosis the kymograms were entirely normal. In 3 of these 4 cases, the infarction was of the posterior wall. In general, localization appeared more accurate with anterior wall infarcts than with posterior wall infarcts, probably due to better visualization of the anterior wall of the left ventricle.

Six patients with coronary artery disease without definite clinical or electrocardiographic evidence of coronary thrombosis showed kymographic changes indicative of an area of infarction.

CONCLUSION

Multiple-slit roentgenkymography is a simple and valuable aid in the diagnosis of myocardial infarction. With its use one is enabled to localize and determine the extent of the infarcted area. Occasionally, as in angina pectoris, or after the subsidence of an acute attack of coronary thrombosis, it may be the only method which will demonstrate that infarction has occurred.

We wish to thank Doctor Richard A. Rendich and the members of the staff of the x-ray department of Kings County Hospital for their assistance in this work, and the physicians of Kings County Hospital for permission to study patients under their care.

REFERENCES

1. Herrick, J. B.: Clinical Features of Sudden Obstruction of the Coronary Arteries, J. A. M. A. **59**: 2015, 1912.
2. Smith, F. M.: The Ligation of Coronary Arteries With Electrocardiographic Study, Arch. Int. Med. **22**: 8, 1918.
3. Herrick, J. B.: Thrombosis of the Coronary Arteries, J. A. M. A. **72**: 387, 1919.
4. Pardee, H. E. B.: An Electrocardiographic Sign of Coronary Artery Obstruction, Arch. Int. Med. **26**: 244, 1920.
5. Parkinson, J., and Bedford, D. E.: Successive Changes in Electrocardiogram After Cardiac Infarction, Heart **14**: 195, 1928.
6. Barnes, A. R., and Whitten, M. B.: Study of the R-T Interval in Myocardial Infarction, AM. HEART J. **5**: 142, 1929.
7. Bell, A., and Pardee, H. E. B.: Coronary Thrombosis, Report of 2 Cases With Electrocardiographic Localization of Thrombus in Right or Left Coronary Arteries, J. A. M. A. **94**: 1555, 1930.
8. Levine, S. A.: Coronary Thrombosis; Its Various Clinical Features, Medicine **8**: 245, 1929.
9. Barnes, A. R., and Mann, F. C.: Electrocardiographic Changes Following Ligation of Coronary Arteries of Dog, AM. HEART J. **7**: 477, 1932.
10. Crawford, J. H., Roberts, G. H., Abramson, D. I., and Cardwell, J. C.: Localization of Experimental Ventricular Myocardial Lesions by Electrocardiogram, AM. HEART J. **7**: 627, 1932.
11. Haney, H. F., Borman, B. C., and Meek, W. J.: Relation between Position of Experimental Myocardial Lesions in Dog and Changes in RS-T Segment of Electrocardiogram, Am. J. Physiol. **106**: 64, 1933.
12. Wolferth, C. C., and Wood, F. C.: Electrocardiographic Diagnosis of Coronary Occlusion by Use of Chest Leads, Am. J. M. Sc. **183**: 30, 1932.
13. Willius, F. A., and Brown, G. E.: Coronary Sclerosis; An Analysis of 86 Necropsies, Am. J. M. Sc. **168**: 165, 1924.
14. Levine, G., Lowman, R. M., and Wissing, E. G.: The Roentgenologic and Electrocardiographic Diagnosis of Coronary Disease, AM. HEART J. **16**: 133, 1938.
15. Stumpf, P., Weber, H. H., and Weltz, G. A.: Roentgenkymographische Bewegungslehre innerer Organe, Leipzig, 1936, Georg Thieme.
16. Hirsch, I. S.: Recording of Cardiac Movements and Sounds by Roentgen Ray, Radiology **22**: 403, 1934.
17. Hirsch, I. S., and Gubner, R.: Application of Roentgenkymography to Study of Normal and Abnormal Cardiac Physiology, AM. HEART J. **12**: 413, 1936.
18. Johnson, S. E.: Roentgen Kymography Considered in Relation to Heart Output and New Heart Index, Am. J. Roentgenol. **37**: 167, 1937.
19. Kirch, E.: Pathogenese und Folgen der Dilatation und der Hypertrophie des Herzens, Klin. Wchnschr. **9**: 817, 1930.
20. Esser, C.: Über das kymographische Verhalten der Herzspitze bei ausgesprochener Dilatation, Fortschr. a. d. Geb. d. Röntgenstrahlen **52**: 213, 1935.
21. Levine, H. D., and Levine, S. A.: Electrocardiographic Study of Lead IV With Special Reference to Findings in Angina Pectoris, Am. J. M. Sc. **191**: 98, 1936.
22. Tennant, R., and Wiggers, C. J.: Effect of Coronary Occlusion on Myocardial Contraction, Am. J. Physiol. **112**: 351, 1935.
23. Applebaum, E., and Nicolson, G. H. B.: Occlusive Diseases of Coronary Arteries; Analysis of Pathological Anatomy in 168 Cases, With Electrocardiographic Correlation in 36 of These, AM. HEART J. **10**: 662, 1935.

THE VALUE AND SIGNIFICANCE OF MULTIPLE CHEST LEADS IN MAN

I. Normal and Hypertrophied Hearts*

A. Bohning, M.D., L. N. Katz, M.D., M. Robinow,† M.D., and G. Gertz, M.D., Chicago, Ill.

CHEST leads may be defined as leads in which one electrode is placed on some part of the chest and the other is applied in such a way that it is little affected by electrical events occurring in the heart. The various chest leads used in clinical electrocardiography[1-8, 10, 11] have been devised to place the chest electrode near the heart. Their diagnostic significance is presumably due to the proximity of the chest electrodes to regions of the heart which have little influence on the standard limb leads.[1, 2, 12]

Diagnostic criteria derived empirically from such leads have greatly enhanced the clinical value of electrocardiography. The use of at least one chest lead appears indispensable for the early diagnosis of cardiac infarcts,[1, 2, 13-21] and frequently aids in detecting the presence of other forms of myocardial involvement.[3, 17, 18, 22-29]

The clinical usefulness of multiple chest leads, however, is not yet well established in spite of several recent series of studies on this subject. Controversial opinions as to the nature of chest leads have made it difficult to evaluate their significance.[6, 9, 10, 11, 30]

The present study represents an attempt to obtain more information concerning the electrical field surrounding the heart by exploring two horizontal cross sections of this field with chest leads, in accordance with the field theory developed by us.[12] It was hoped that with such information multiple chest leads might gain diagnostic significance beyond their purely empirical associations.

METHODS

In a total of about 200 cases of all types, multiple anterior chest leads were analyzed, and in some 50 cases both anterior and posterior chest leads were studied. This report deals only with anterior chest leads in 25 cases and both anterior and posterior chest leads in 23 cases. All 25 subjects examined with anterior chest leads alone were normal. Of the subjects examined with anterior and posterior chest leads, 5 were normal, 5 had right ventricular preponderance (Fig. 5 B), as shown by the presence of an inverted QRS in Lead I (in some, together with depression of S-T and inversion of T in Lead III), 5 had left ventricular preponderance of type I (Fig. 5 C), as shown by inversion of QRS in Leads II and III without any notable change in S-T and T in Lead I, and 8 had left ventricular preponderance of type II (Fig. 5 D), as shown by inversion

*Aided by the A. D. Nast Fund for Cardiac Research and the Kuppenheimer Fund.
†Dept. of Pediatrics, University of Georgia, School of Medicine, Augusta, Ga.
From the Cardiovascular Department, Michael Reese Hospital, Chicago, Ill.
Received for publication Nov. 21, 1938.

of QRS in Lead III (or Leads II and III) and depression of S-T in Lead I (and II), and inversion of T in Lead I (and II).

All chest leads were standardized so that 1 millivolt produced a deflection of 1 centimeter. The left leg was chosen for the site of the "indifferent" electrode. Electrode connections were such that relative positivity of the chest electrode gave a downward deflection.* The various points at which chest electrodes were placed, together with abbreviations employed in this report, are shown in Figs. 1 and 2, which are diagrams adapted from published necropsy material.[31] These figures, as well as Figs. 3 and 4, illustrate the topographic relations between the points used and the structure of the heart.

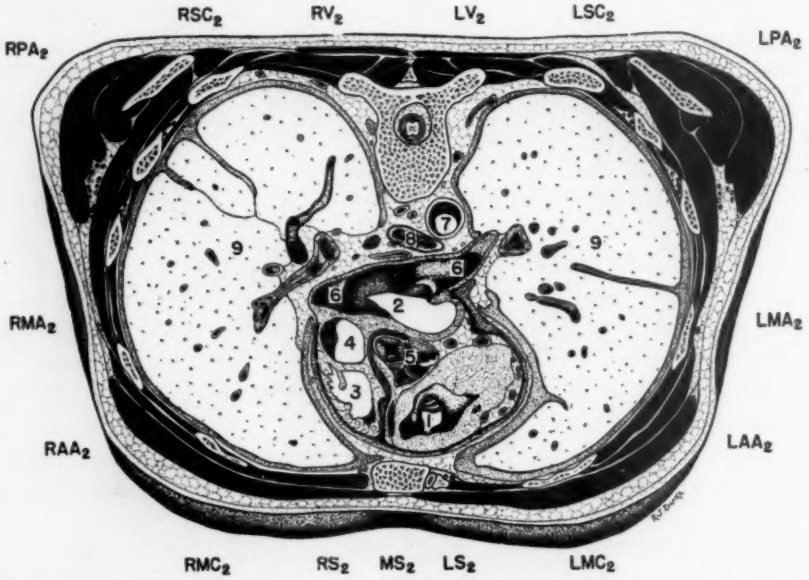


Fig. 1.—Cross section through chest at level of upper margin of third costal cartilage. Modified from sec. 25 of Eycleshymer and Schoemaker.[31] MS_2 represents point at the level of second intercostal space in midsternal line; LS_2, in left parasternal line; LMC_2, in left midclavicular line; LAA_2, in left anterior axillary line; LMA_2, in left midaxillary line; LPA_2, in left posterior axillary line; LSC_2, in left scapular line; LV_2, in left paravertebral line; RS_2, RMC_2, RAA_2, RMA_2, RPA_2, RSC_2, and RV_2, homologous points on right side. 1 is right ventricle, 2 is left ventricle, 3 is right auricle, 4 is superior vena cava, 5 is aortic valve, 6 is pulmonary vein, 7 is descending thoracic aorta, 8 is esophagus, and 9 is lungs.

DISCUSSION OF RESULTS

Figs. 6 and 7 show typical records from chest leads with electrodes at various points around the chest at the level of the second and fourth intercostal spaces in the normal subject (*A*), in a patient with right ventricular preponderance (*B*), and in two patients with the two types of left ventricular preponderance (*C* and *D*). These illustrate the general pattern of curves obtained in each of these four categories of patients.

*This is the reverse of the procedure adopted by the American Heart Association. The records were obtained before the report of the American Heart Association was published. The connection we employed makes the chest lead directly comparable to Leads II and III. In Leads II and III relative positivity of the electrode nearer the heart, the right and left arm electrode, respectively, also gives a downward deflection. Lead I should be considered as differing from all of the other leads used in this report, for, unlike Leads II and III, it is really the algebraic sum of electrical effects of electrodes approximately equidistant from the heart. On this account, we feel that the old expression Lead II = Lead I + Lead III should be superseded by Lead I = Lead II − Lead III.

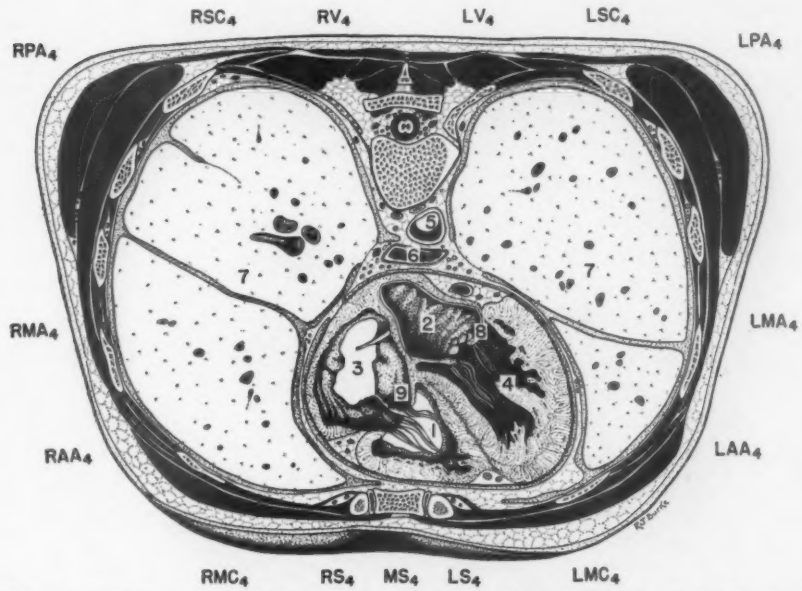


Fig. 2.—Cross section through chest at level of sternal end of fourth costal cartilage. Modified from sec. 26 of Eycleshymer and Schoemaker.[31] MS_4, LS_4, LMC_4, LAA_4, LMA_4, LPA_4, LSC_4, LV_4, RS_4, RMC_4, RAA_4, RMA_4, RPA_4, RSC_4, and RV_4 represent points equivalent to MS_2, etc., except that they are at the level of the fourth intercostal space, instead of the second. 1 is the right ventricle, 2 is the left auricle, 3 is the right auricle, 4 is the left ventricle, 5 is the descending thoracic aorta, 6 is the esophagus, 7 is the lung, 8 is the mitral valve, and 9 is the tricuspid valve.

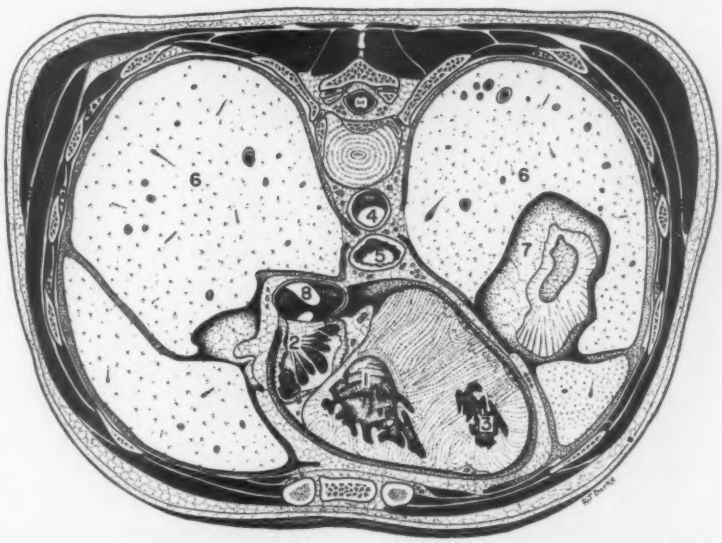


Fig. 3.—Cross section through chest at level of sternal end of fifth costal cartilage. Modified from sec. 27 of Eyscleshymer and Schoemaker.[31] 1 is right ventricle, 2 is left auricle, 3 is left ventricle, 4 is descending thoracic aorta, 5 is esophagus, 6 is lungs, 7 is diaphragm, and 8 is inferior vena cava.

GENERAL PATTERNS

While varying in detail, the following characteristics of the chest leads are common to the 200 subjects studied by us.

(a) There is an orderly pattern of transition from one point on the chest to the next, as regards the sequence and size of the deflections of the QRS complex, the direction of the S-T segment deviation, and the size and direction of the T wave.

(b) The magnitude of the deflections is greater over the anterior chest wall than over the posterior wall.

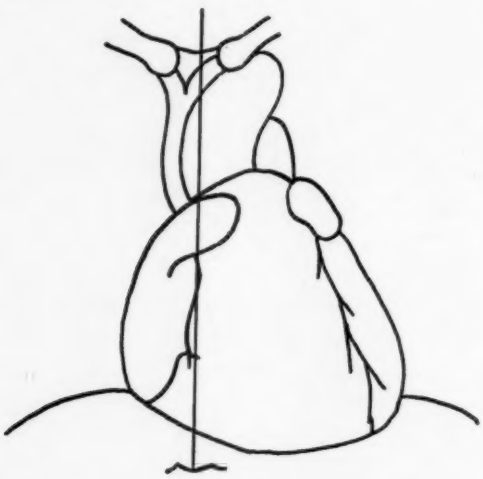


Fig. 4.—Diagram of frontal silhouette of heart.

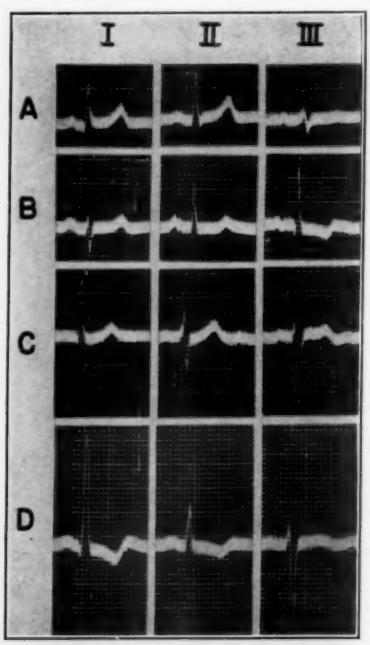


Fig. 5—Segments of standard limb-lead electrocardiograms. *A*, normal subject; *B*, patient with right ventricular preponderance (rheumatic fever with mitral stenosis), and *C* and *D*, two patients with left ventricular preponderance (hypertension). Discussed in text.

(c) At the level of the fourth intercostal space there is a tendency for records from chest points 180° apart to be mirror images of each other.

(d) In going around the chest the QRS complex tends to change from an upright to a diphasic deflection with the first phase directed downward, then to become inverted, then to become diphasic with the first phase directed upward, and, finally, to return to its original contour.

(e) In going around the chest there is a tendency for the T wave to change from an inverted to an upright deflection, and back again. In the transition the T wave may become diphasic.

(f) The S-T segment and T wave usually appear as a single continuous element.

Certain relations were also found between the chest leads and the limb leads, as follows:

(1) Lead LMA_4 is usually the inverse of Lead I. Sometimes, however, LAA_4 is more nearly the inverse of Lead I.

(2) Leads RSC_2 and RPA_2 are almost identical with Lead II.

(3) Leads LSC_2 and LPA_2 are almost identical with Lead III.

FINDINGS IN THE NORMAL HEART

The chest leads shown in *A* of Figs. 6 and 7 are typical for normal young adults. Their general pattern is remarkably constant. Starting in the fourth intercostal space at the left parasternal line, the QRS is diphasic, showing a preliminary downward deflection which increases in depth as the chest electrode moves across the left chest to the anterior axillary line. At the same time, the second upright deflection becomes smaller, then disappears and is replaced by a primary upright phase in the left midaxillary line. On going to the right around the posterior chest wall, the first upright phase increases in height, while the downward deflection decreases and finally disappears in the right midaxillary line. In the right axilla, a preliminary dip reappears and increases in size on going to the right anterior chest.

The S-T segment and the T wave in the left parasternal line are both directed downward. Their deviation from the isoelectric line increases at first as the chest electrode is moved across the chest to the left, but decreases again as the left axilla is approached. In the region of the left scapula both S-T and T are directed upward. The upward deviation waxes as the electrode is moved to the right across the posterior chest, to wane again in the right axilla. The transition from upright to inverted deflections occurs in the region of the sternum. In the midsternal lead a diphasic T wave is found, with the first phase directed downward.*

*The pattern in dogs[32] is in general similar to that in man, differing in minor details.

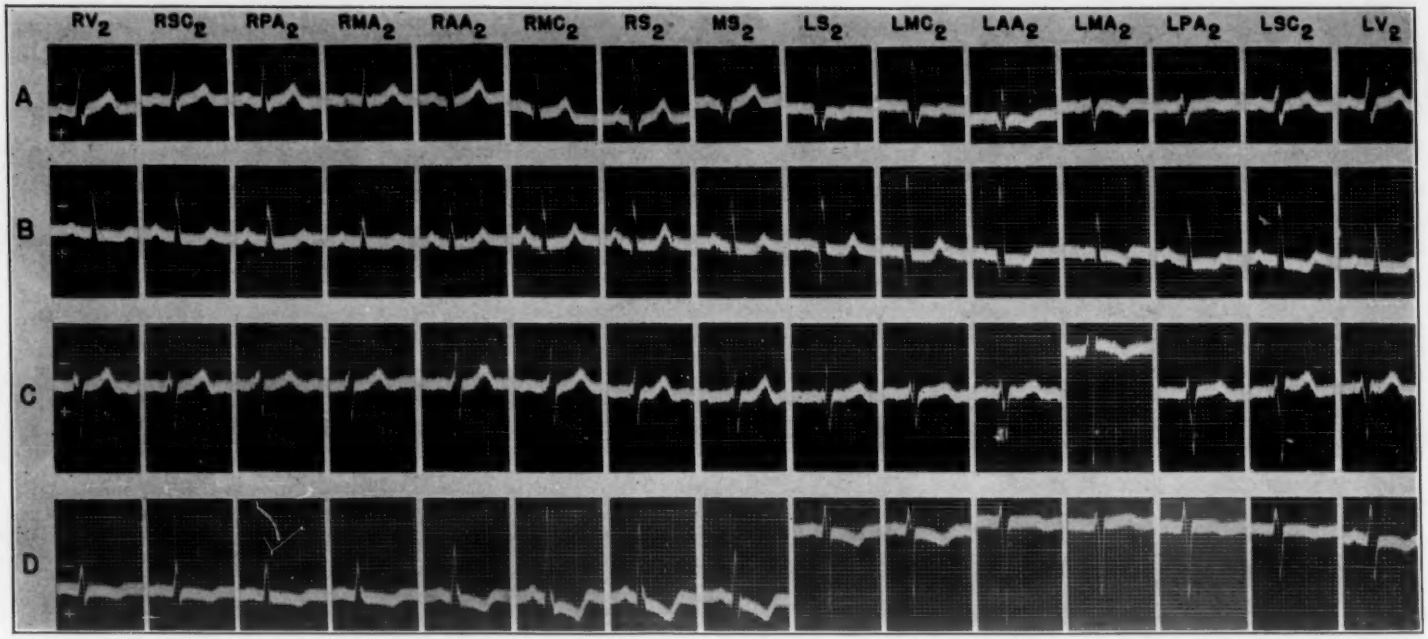


Fig. 6.—Segments of chest lead electrocardiogram in patients A, B, C, and D, referred to in Fig. 5, using chest points indicated in Fig. 1, with the "indifferent" electrode on the left leg. + and – indicate relative positive and negative potential of chest electrode with respect to the leg. The curves are the inverse mirror image of those obtained by following the recommendation of the American Heart Association Committee's recent report.[4, 5] For this study, the curves as presented are comparable to Leads II and III. Discussed in text.

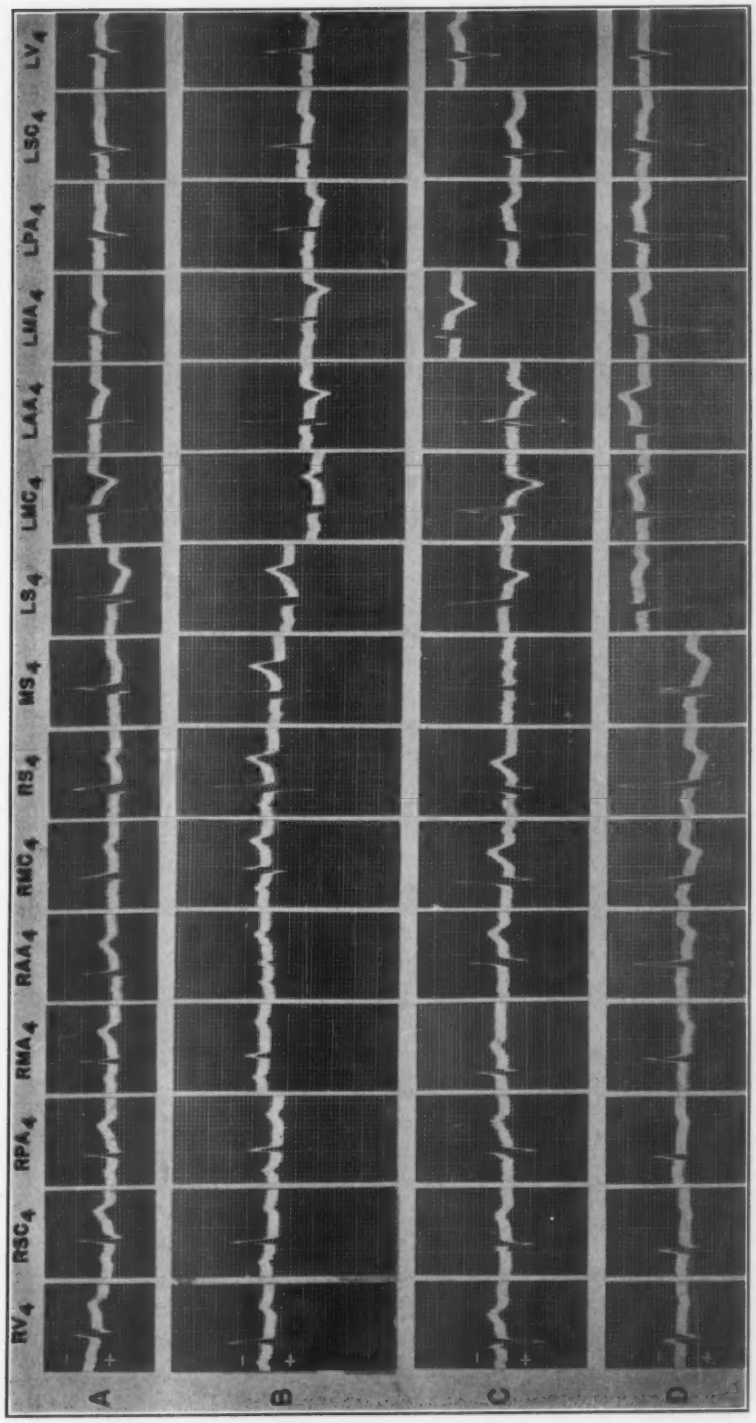


Fig. 7.—Segments of chest lead electrocardiograms in patients A, B, C, and D referred to in Fig. 5, using chest points indicated in Fig. 2, with the "indifferent" electrode on the left leg. Conventions as in Fig. 6. Discussed in text.

A similar pattern exists at the level of the second intercostal space, but the QRS is triphasic and W-shaped over the left anterior chest wall.

When the chest leads and Leads II and III are correlated with the relation of the various electrode positions to the anatomical structure of the heart, the following facts can be established in normals:

1. Near the base of the heart the QRS, S-T, T and P deflections are directed mainly upward.

2. Near the apex of the heart the QRS, S-T, T and P deflections are directed mainly downward.

3. Over the right ventricle and about equidistant from the apex, base, and septum, QRS is diphasic with the first phase directed downward, S-T is depressed, and T is inverted.

4. Over the left ventricle and about equidistant from the apex, base, and septum, QRS is diphasic with the first phase directed upward, S-T is elevated, and T is upright.

FINDINGS IN RIGHT VENTRICULAR PREPONDERANCE

The chest leads in preponderant hypertrophy of the right ventricle (Figs. 6 B and 7 B) differ considerably from the normal, as follows:

1. The QRS complex over the area of absolute cardiac dullness is considerably greater than normal, and the second upright phase is as tall, or taller, than the first downward phase.

2. No entirely inverted QRS, or diphasic QRS with the first phase directed upward, is seen anywhere.

3. The smallest QRS at the level of the fourth intercostal space is in the right anterior axillary line. The increase in the magnitude of QRS on going over the anterior chest to the left is striking.

4. Both the upright and inverted T waves show a greater amplitude than normal in the area of absolute cardiac dullness.

5. The T wave is upright over the entire right chest anteriorly, so that the transition from upright to inverted T waves is shifted to the left. It occurs between the left midclavicular and anterior axillary lines.

6. The other transition, from inverted to upright T waves, is shifted to the right. It occurs posteriorly between the left and right vertebral lines; at this point the T wave is diphasic.

FINDINGS IN LEFT VENTRICULAR PREPONDERANCE

Two types of limb lead electrocardiograms can be distinguished in cases of preponderant hypertrophy of the left ventricle. In one type, QRS is directed downward in Leads II and III, but the T wave remains upright in all three leads. In the other, QRS is directed downward either in Lead III alone or in both Leads II and III; in Leads I and II the T wave becomes inverted and the S-T segment becomes depressed. The latter type resembles the common type of bundle branch block, but the

duration of QRS is less than 0.12 sec. The illustrated curves (Figs. 5 C and D, and 6 and 7 C and D) are typical, but intermediate forms are also seen.

In the first type of left ventricular preponderance (Figs. 6 C and 7 C) the following chief differences from the normal are found:

1. The QRS complex is larger than normal over most of the chest, especially in the left midaxillary and posterior axillary lines. The QRS complex is largest in LMA_4, whereas in right ventricular preponderance the maximum is at MS_4.

2. The points at which upright, inverted, and diphasic QRS complexes appear at the level of the fourth intercostal space are shifted to the left on the anterior surface of the chest and to the right on the posterior surface. At the level of the second intercostal space the QRS complex is diphasic, with the first phase directed upward at all points.

3. The direction of the T wave and the S-T segment at the level of the fourth intercostal space is generally the same as in the normal, but the S-T deviations and T deflections are larger. At the level of the second intercostal space the T wave is upright at all points except at LMA_2.

The second type of left ventricular preponderance (Figs. 6 D and 7 D) presents the following chief differences from the normal:

1. The QRS complex is larger than normal over the whole chest except the right posterior portion. Especially striking is the increase in the region between the left midclavicular line and the left midaxillary line. This is to the right of the region of maximum QRS excursion in the first form of left ventricular preponderance, and to the left of that in right ventricular preponderance.

2. The transition from an upright to an inverted QRS complex over the anterior chest wall is more abrupt than normal, occurring between RS_4 and LS_4. The QRS complexes at the level of the second intercostal space differ from those in the first type of left ventricular preponderance in that they are upright, not diphasic, over the right anterior and posterior chest wall.

3. Unlike in the first form, the T wave and S-T segment in the second type of left ventricular preponderance are the inverted mirror images of their normal appearances in all chest leads studied.

THE DIAGNOSTIC SIGNIFICANCE OF CHEST LEADS IN PREPONDERANT HYPERTROPHY

The above characteristics of the various chest leads depict the chief deviations from normal in preponderant hypertrophy of the right and left ventricles. Variations which occur from subject to subject can be explained by differences in chest contour, in position of the heart, in the amount of damage to the conduction system and heart muscle, in the degree of hypertrophy and dilatation of the chamber chiefly involved, and in the amount of dilatation and hypertrophy of the other heart chambers, especially the other ventricle.

The changes in the chest leads are probably as characteristic as the changes which are utilized to recognize right and left ventricular preponderance in the standard limb leads. The diagnostic significance of the ratio of the magnitude of QRS over the sternum and that over the left axilla has already been reported by other observers,[6, 10, 11, 29]

MEANING OF CHEST LEADS IN TERMS OF THE ELECTRICAL FIELD THEORY

(a) *The Source of the Electrical Field.*—As outlined previously,[12] the electrical manifestations of the heartbeat form a three-dimensional electrical field. The characteristics of this field depend on (a) the conductivity and shape of the medium in which the electrical currents flow, and (b) the nature of the current source. In a previous communication[12] evidence was presented to show that the electrical medium has the shape of the torso of the body; the extremities, head, and neck have very little influence. This medium is composed of various electrical conductors, their arrangement being complicated by the eccentric position of the heart. The different qualities of these electrical conductors and consequently their different influence on the electrical field of the heart have been demonstrated in the dog whose chest is closed[32] by a method similar to that used for the dog whose chest is open.[43] A new concept[12] based on these experimental facts has served as a convenient working hypothesis in clinical electrocardiography.[44]

More important than the medium is the source of the electrical field. When the heart is in situ, it has been established[33] that small batteries of closely adjacent positive and negative electrical elements appear within the heart during the periods of activation and recovery wherever regions in different states of activity and recovery are in juxtaposition. These batteries lie at the junction between relatively active and inactive regions, and between the relatively recovered and unrecovered regions. They are the source of the electrical field.

It is desirable to define the pattern of activation and recovery in the heart. The impulse travels down the common bundle and its branches, and then along the Purkinje network, which, as recent work has shown, extends into the myocardium itself.[34] The batteries can therefore be imagined to start at a point approximately at the junction of the upper and middle thirds of the septum, halfway between the anterior and posterior interventricular grooves, where the Purkinje fibers begin to flare out. From this point they spread in a radial fashion in the septum, assuming that there is fairly uniform spread through the Purkinje network. The dimensions of the septum are such that the battery front reaches a point on the anterior and a point on the posterior interventricular groove ahead of other parts of the surface of the heart. From these two points four battery fronts travel over the outer walls of the ventricles, still keeping the more or less circular outline, with the center of radiation at the point in the septum previously mentioned. Since the

left ventricle is normally larger and thicker than the right, the battery fronts spreading over its walls dominate those spreading over the right ventricle.

It must be borne in mind that activation of a single region occupies several hundredths of a second, the duration of the sharply ascending portion of the monophasic action curve of a single region. This time span required for completing the activation of each point of the ventricles alters the location and dimensions of the batteries during the invasion of the ventricles.

Recovery begins soon after invasion and occupies most of the electrical systole, as demonstrated by the early decline of the monophasic action curve. The relatively long period of recovery establishes a second battery group, which occupies the second part of ventricular activity. As the slope of the monophasic curve indicates, the rate of recovery is slow at the beginning, increases gradually, and abruptly slows at the end. It never attains the speed of the activation process. The strength of the second battery group changes with the rate of recovery, quickly disappearing when recovery is completed. Completion of recovery is not synchronous in all parts of the ventricles, and this asynchronism is not determined entirely by the pattern of invasion.

Thus, two complex batteries appear in succession during ventricular activity, one occupying the invasion period and the other the entire recovery period. The first is a large battery of varying intensity; the second is smaller, attains its maximum slowly, and then fades out more abruptly than it developed. These two successive batteries are complex as regards voltage, position, shape, and area of their poles, and these characteristics change from moment to moment.

(b) *The Determination of the Surface Field in a Horizontal Plane at the Level of the Sternal End of the Fourth Intercostal Space.*—No direct information is available concerning the electrical field within the human body. But the field on the surface of the body can be mapped out from moment to moment, and can be defined by the following qualities: (1) the position of the zero potential lines, (2) the location and extent of the positive and negative fields, and (3) the concentration of potential lines in various regions of the surface.

In this report we present data derived from the exploration of a horizontal plane at the sternal level of the fourth intercostal space, as described above. The surface distribution of potential in this plane was determined at four points in the heart cycle, namely, 0.03, 0.07, 0.24, and 0.32 second after the beginning of the QRS complex. The first two points occur during the first and last thirds of the QRS complex; the last two points are situated on the first and second halves of the T wave. Changes of the surface field between these four points can be readily surmised. The outline of these four surface fields is somewhat inaccurate, since the points selected in the various chest leads are only

approximately homologous, and because the leg electrode is not quite "indifferent." Nevertheless, this approach seems accurate enough to show the genesis of the electrocardiogram obtained at various points on the chest. The relative potential of the chest electrodes at each of the four moments selected is illustrated for the normal heart (Fig. 8 A, B, C, and D) and for the different types of preponderant ventricular hypertrophy (Figs. 9, 10, and 11). The numerals on the chart represent multiples of 0.1 millivolt. In each of the sixteen diagrams the positions of the zero potentials are indicated, and lines are drawn to show the spacing on the surface of potential lines differing from each other by 0.1 millivolt. The points of maximum positive and negative potential are marked + and –, respectively.

1. THE SURFACE FIELD IN THE NORMAL HEART

The electrical field on the surface of the chest during the first stage of activation of the ventricles (Fig. 8 A) has a greater concentration of positive potential lines and a greater maximum positive potential than the negative field. The maximum positive potential is in the regions of LMC_4, the maximum negative potential, in the region of RPA_4 and RSC_4. The line of zero potential is between RAA_4 and RMC_4 and between LPA_4 and LMA_4. During the latter part of the period of activation (Fig. 8 B), the field rotates about 90° in a counterclockwise direction when viewed from above. The maximum positive potential now lies in the region of LPA_4, and the maximum negative potential in the region of MS_4. The zero potential lines have shifted to LAA_4, and between RPA_4 and RMA_4. During invasion, the surface field waxes at first, rotates in a counterclockwise direction about 90°, and then wanes. The surface field during recovery is never as strong as that developed during activation and does not rotate much; the location of the maximum positive and negative surface potentials and of the lines of zero potential is similar to that during the first stage of activation.

Despite the complexity of the batteries occurring during electrical systole and the heterogeneity of the electrical conductors adjacent to the heart, the pattern in this plane can be readily correlated with the patterns of activation and recovery outlined above, and with the topographic anatomy of the heart. Figs. 1 to 4 show (1) that the heart is closer to the front than to other parts of the chest surface, and that this frontal surface is formed chiefly by the right ventricle; (2) that the right and left ventricles share the diaphragmatic surface about equally; (3) that the ventricular septum is almost entirely to the left of the midline; and (4) that it runs obliquely downward from right to left, forming an angle of about 45° with the midline.

During the first part of activation, the batteries start in the upper third of the septum midway between the anterior and posterior interventricular grooves, and, as they move anteriorly, downward, and to the left, they wax in strength as the extent of the area of junction between

active and inactive regions grows. By virtue of the spread of activation through the septum, the positive pole, in as yet inactived tissue, lies, in general, more toward the apex of the heart and the anterior and lower part of the trunk than the negative pole in activated tissue. This accounts for the distribution of the surface field. The rotation of the field at the time when the potential strength at the surface of the chest is largest coincides with the spread of activation from the septum to the outer walls of the ventricles. The batteries over the right ventricle are directed opposite to those in the left, and hence tend to neutralize somewhat the surface field produced by the latter. But since the left ventricle normally is greater in area and thickness, the batteries over this ventricle dominate those of the right. The

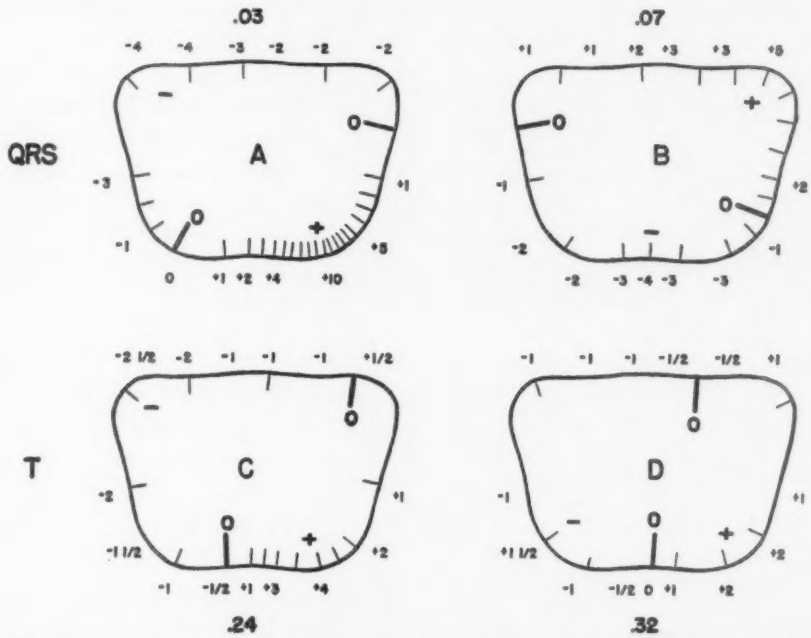


Fig. 8.—Cross-section diagrams A, B, C, and D represent the distribution of surface potential in normal subject at level of sternal end of fourth intercostal space 0.03, 0.07, 0.24, and 0.32 sec., respectively, after onset of QRS. Potential values are expressed in terms relative to leg potential, in multiples of 0.1 of a millivolt. Dis- Discussed in text.

batteries in the anterior and posterior walls of the left ventricle spread laterally toward the posterior axillary line. Therefore, the positive pole of the major battery lies, at this time, in general, lateral and somewhat posterior to the negative pole. This represents a rotation of about 90° in a plane approximately parallel to the horizontal plane depicted. It corresponds to the field rotation noted at this time. As the activation process is completed, the batteries fade out.

The orientation of the surface field during the recovery process, with maximum positive potential to the left and maximum negative potential to the right, suggests that the base and lateral walls of the right ventricle

lag behind the apex and left ventricle in their recovery. This is in accord with data on the relative duration of the mechanical systole in the two ventricles,[35] and again emphasizes how little the pattern of recovery normally depends on the pattern of invasion.[36]

2. THE SURFACE FIELD IN RIGHT VENTRICULAR PREPONDERANCE

The pattern of the surface field differs considerably from the normal (compare Figs. 8 and 9), as follows:

Activation.—The field in the first part of activation is oriented similar to the normal as regards the location of the lines of zero potential and of the maximum negative and positive fields. However, the concentration of positive potential lines is much greater on the anterior surface, the maximum potential is considerably greater, and the area of maximum potential is displaced to the left to MS_4. At the same time the maximum negative potential is somewhat smaller. In the stage of activation, when the field rotates the positive field disappears from the horizontal plane depicted, and the maximum negative potential comes to lie near the point of maximum positive potential. This indicates that the field has rotated markedly in a plane located at a large angle from the horizontal, and that the positive field must be located somewhere in the lower chest, probably posteriorly. In the second stage of invasion, the concentration of the potential lines over the front of the chest, as well as of the maximum negative potential, remains much greater than normal.

Recovery.—While the maximum positive potential lies in the normal region, the maximum negative potential is displaced in a counterclockwise direction towards MS_4, and comes to lie close to the point of maximum positive potential. The concentration of the potential lines is decreased over the right posterior quadrant and increased over the left anterior quadrant. There is, furthermore, little rotation of the field during recovery.

Anatomic Correlation.—These changes in the field can be correlated with the changes in the pattern of invasion and retreat which accompany hypertrophy of the right ventricle. These changes are partly due to positional changes of the heart accompanying this condition, and partly to the effect of the increased mass of the right ventricle. In hypertrophy of the right ventricle, this chamber moves downward on the diaphragm and forward to gain closer contact with the front of the chest. The vertical height of the right ventricle is increased, and the area presenting itself anteriorly exceeds that on the diaphragm. The anterior interventricular groove is displaced to the left, and the septum bulges less into the right ventricle. The septum also lies more nearly vertical, losing some of its tilt to the left.

As activation begins, the batteries at equivalent moments during the spread through the septum come closer to the anterior chest wall, accounting for the increased concentration of potential lines here and the

decreased concentration posteriorly. The displacement of the septum and the greater mass of the right ventricle alter the summation of the batteries over the outer walls of the two ventricles during the second stage of invasion. The batteries in the outer wall of the right ventricle are more dominant because the enlarged right ventricle is closer to the front of the chest and occupies more of its surface area. These circumstances bring about an abnormal angulation of the field. The orientation of the field in the second phase of activation indicates that the spread which dominates is the one from the anterior surface backward, to the right, and downward. This is the manner in which the activation can be imagined to spread over the walls of the hypertrophied right ventricle, presenting itself beneath the anterior chest wall. The field distribution during recovery also fits the view that recovery in the hypertrophied right ventricle and the base of the heart lags behind that in the apex and left ventricle.

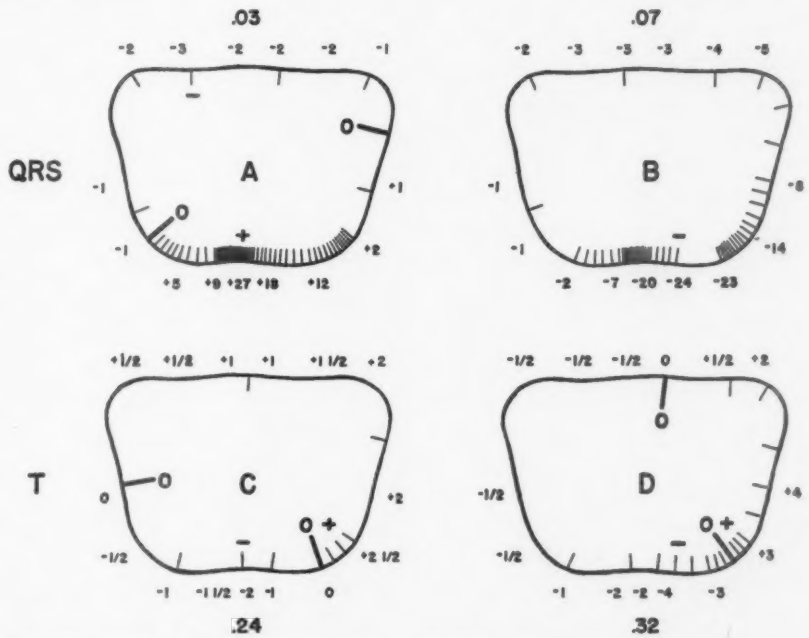


Fig. 9.—Cross-section diagrams A, B, C, and D represent the distribution of surface potential obtained as in Fig. 8 from subject with right ventricular preponderance. Discussed in text.

3. THE SURFACE FIELD IN LEFT VENTRICULAR PREPONDERANCE

A. *First Type.*—In the first type of left ventricular preponderance (Figs. 8 and 10) the chief differences from the normal are the following:

(a) During the first stage of activation the lines of zero potential are closer together than normal, being located at LMC_4 and LMA_4. The positive field is smaller in area and weaker than normal, while the negative field is larger and stronger. The greatest concentration of potential

lines is located over the sternum, instead of the anterior axilla (A of Figs. 8 and 10).

(b) The rotation of the field is less than normal (about 30°), although in the same direction.

(c) In the second stage of activation the zero lines are still close together, the first now being at LAA_4 and the second close to RMC_4. The positive field has grown greatly in area and strength while the negative field has shrunk in area and strength. The greatest concentration of potential lines is now located in the anterior part of the left axilla, and their strength over the entire chest surface is greatly in excess of the normal.

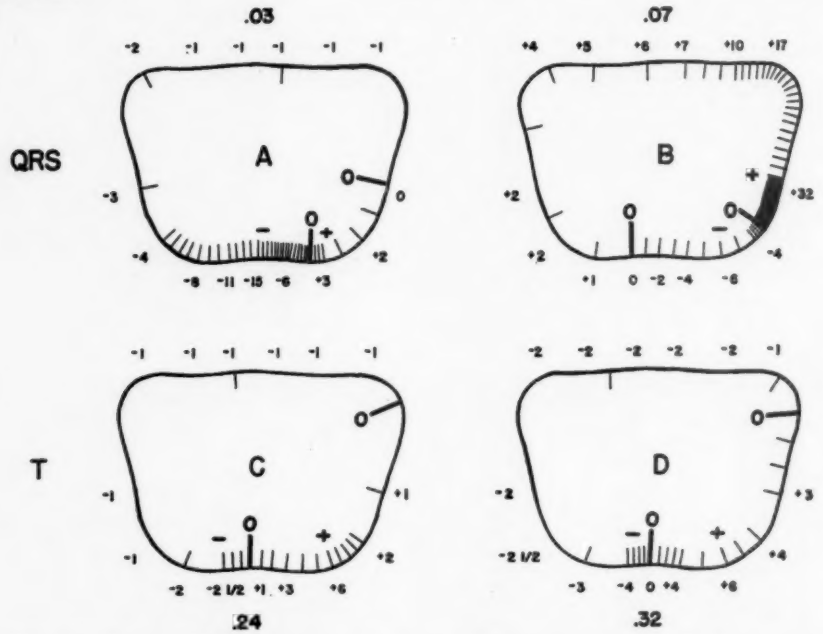


Fig. 10.—Cross-section diagrams A, B, C, and D represent the distribution of surface potential obtained as in Fig. 8, from subject with first type of left ventricular preponderance. Discussed in text.

(d) During recovery, the field is more concentrated anteriorly and laterally than normal, and the maximum negative potential lies closer to the maximum positive potential. There is practically no rotation of the surface field during the recovery period, and the general orientation is similar to the normal.

B. *Second Type.*—In the second type of left ventricular preponderance, the surface field resembles the normal field more closely during activation, but differs entirely from the normal during recovery.

The chief differences between this second type of left ventricular hypertrophy and the normal are the following (Figs. 8 and 11):

(a) In the first stage of activation the lines of zero potential, the maximum positive potential, and the maximum negative potential are

displaced in a counterclockwise direction from their normal positions. The strength of the positive and negative fields and the concentration of potential lines are increased, particularly over the left anterior quadrant.

(b) The rotation of the field, as in the first type of left ventricular preponderance, is less than normal (about 30°) and in the same direction.

(c) In the second phase of activation, the concentration and magnitude of the positive and negative fields are greater than normal.

(d) During recovery, the location of the positive and negative fields is almost the reverse of the normal.

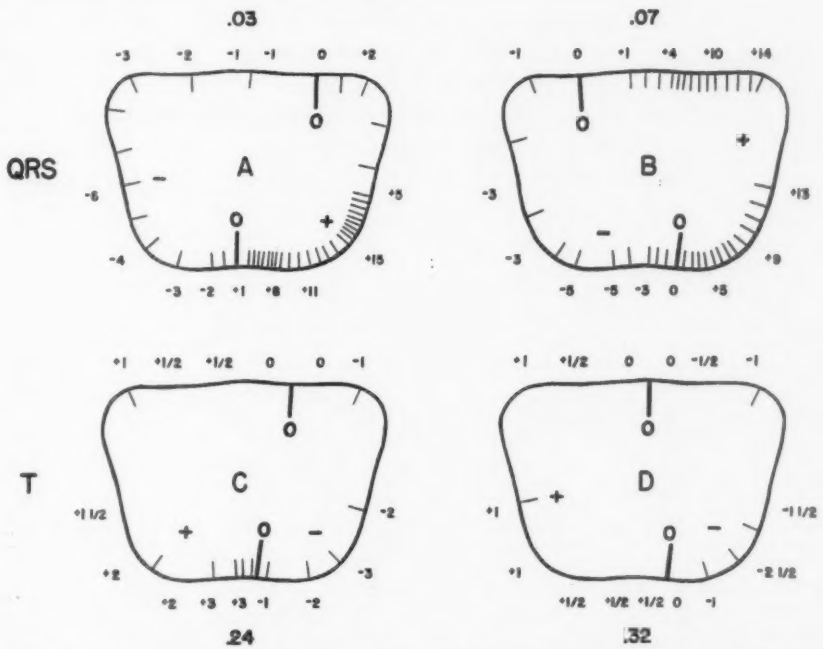


Fig. 11.—Cross-section diagrams A, B, C, and D represent the distribution of surface potential obtained as in Fig. 8, from subject with second type of left ventricular preponderance. Discussed in text.

C. *Anatomic Correlation.*—These changes in the surface field in left ventricular preponderance fit the following known changes of the heart in this condition: the area and mass of the left ventricle are increased; the heart elongates to the left and downward and rotates counterclockwise on its long axis, so that the left ventricle comes in more intimate contact with the paravertebral muscle mass; the anterior interventricular groove and the right ventricle are displaced to the right; and the septum runs more nearly vertically and bulges much more than normally into the right ventricle, and so lies closer to the anterior chest wall.

With activation beginning in the septum, the fact that it lies closer to the anterior chest wall accounts for the greater field strength here during

the first phase of activation. The shift in the septum explains the displacement of the field in a counterclockwise direction during this phase of activation. Since under these circumstances the battery front spreads from left to right in the septum as well as over the outer wall of the hypertrophied left ventricle, the degree of rotation of the field will be less than normal during the passage of the battery front from the septum to the outer wall of the ventricles. The closer contact of the heart with the chest wall over the left anterior and axillary regions explains the greater magnitude and concentration of the potentials over this region.

The orientation of the field during recovery is the chief distinguishing characteristic between the two types of left ventricular preponderance. In the first, the pattern of recovery is like the normal, indicating that recovery lags in the base and right ventricle behind the apex and left ventricle. The complete reversal of the field from normal during recovery in the second type of left ventricular preponderance is evidence that, probably because of the great hypertrophy of the left ventricle and advanced heart muscle changes, there is a lag of recovery in the left ventricle, i.e., the pattern of recovery is set by the pattern of activation.

A CONSIDERATION OF THE VARIOUS THEORIES OF THE SURFACE FIELD

The surface fields shown in Figs. 8 to 11 are asymmetric and show peculiar concentrations and spreads of potential lines. Obviously, these fields cannot be produced by a single bipole changing its voltage and direction from moment to moment, nor even by a pair of simultaneous bipoles. However, these results agree with our amplification[12, 44] of Waller's proposition, namely, that the field is produced in a heterogeneous conducting medium by a complex battery which changes its pattern, voltage, position, and distance between poles in a complex way from moment to moment. We regard the concept of Eyster and his collaborators[37, 38, 39] of two bipoles moving simultaneously and independently during activation of the heart, and another pair during recovery, as an oversimplification. This criticism applies even more to the ideas of Groedel and his associates.[11] The three-dimensional vector diagram which Schellong and his associates,[40] among others, have recently utilized, does not give the complete picture of what is happening, even though it may offer diagnostic possibilities.

Our results do not support the view of Wilson and his collaborators[41] that the anterior chest leads depict, preferentially, events in regions of the heart beneath the chest electrode. The distance from the surface of the heart to the anterior chest wall is sufficient to minimize the effect of any one small area of the heart. The sharp reversal in direction of QRS and its orderly time pattern on the anterior chest also fit our concept. If leads from the anterior chest were "semidirect," as claimed by Wilson, et al.,[41] then esophageal leads close to the left ventricle, pos-

teriorly, should also be "semidirect," and the record from the esophageal lead should resemble in contour that obtained over the anterior wall of the chest and that from a unipolar lead directly from the heart's surface. This is not the case.[32, 42] With the esophageal lead, the QRS phase sequence is the reverse of that in unipolar leads made directly from the heart's surface and of that in anterior chest wall leads. Except for their larger magnitude, esophageal leads[42] resemble leads from the posterior chest wall. Experience gained with the esophageal lead is in accord with our field theory. It follows that the data derived from chest leads by Wilson's school cannot be accepted as indicating the sequence of activation of the ventricles. The sequences measured by Wilson appear to represent merely the time at which the various points on the chest enter the negative part of the surface field as it rotates during the passage of activation from the septum to the outer walls of the ventricles. Hence, the evidence based on chest leads advanced by Wilson and his collaborators on the order of activation of the two ventricles in intraventricular block must be held sub judice.

THE VALUE OF MULTIPLE CHEST LEADS

We have presented evidence which supports the theory that the time record of the various points on the upper chest, including the right and left arms (Leads II and III), represents the fluctuation of the electrical field in a heterogeneous conducting medium, generated by the complex, constantly changing battery occurring in the heart during ventricular activity. The patterns developed can be correlated with the anatomic and functional experimental evidence in both normal and hypertrophied hearts.

Further investigation may show that multiple chest leads give a better index of ventricular hypertrophy than do the standard limb leads. This is suggested by the fact that definite patterns can be obtained from multiple chest leads which lend themselves to analysis on a deductive physiologic, instead of an empirical, basis. A relatively small number of chest leads, labelled CF_1, CF_2, CF_3, CF_4, CF_5, and CF_6 in the recent report of the American Heart Association,[5] may be sufficient to obtain information for clinical purposes.

Further studies of multiple chest leads in other conditions will be presented by us in subsequent reports.

SUMMARY

1. Electrocardiograms were obtained from various points on the chest wall in normal subjects and in the patients with right and left preponderant ventricular hypertrophy.

2. These records were used to reconstruct and analyze the changing surface electrical field of the heart during the phases of electrical systole.

3. Electrocardiograms from chest leads were interpreted as potential fluctuations in a heterogeneous conducting medium of an electrical field, generated by a series of complex, constantly changing batteries.

4. These fluctuations follow a definite pattern: (1) a period of waxing potential during activation of the septum, (2) a period of rapid rotation of the field as activation spreads from the septum to the outer wall of the ventricles, (3) a period of waning as activation of the outer ventricular walls is completed, and (4) a waxing and waning of potential, with slight rotation, during recovery.

5. The pattern in preponderant hypertrophy of the ventricles differs considerably from the normal. The differences can readily be correlated with changes in the spread of the batteries and in the arrangement of the conducting medium which are known to occur under such conditions. These patterns were remarkably constant and characteristic in the types of hearts studied.

6. The constancy of these patterns and their new interpretation lend a new significance to multiple chest leads.

We are indebted to the several internes and Heart Station technicians for assistance in obtaining the records, and to Mr. Russell Burke for making the drawings.

REFERENCES

1. Wolferth, C. C., and Wood, F. C.: Electrocardiographic Diagnosis of Coronary Occlusion by Use of Chest Leads, Am. J. Med. Sci. **183**: 30, 1932.
2. Wilson, F. N., Macleod, A. G., Barker, P. S., Johnston, F. D., and Klostermeyer, L. L.: The Electrocardiogram in Myocardial Infarction With Particular Reference to the Initial Deflections of the Ventricular Complex, Heart **16**: 155, 1933.
3. Roth, Irving R.: On the Use of Chest Leads in Clinical Electrocardiography, AM. HEART J. **10**: 798, 1935.
4. Committee of the American Heart Association on Chest Leads—Standardization of Precordial Leads, J. A. M. A. **110**: 395, 1938.
5. Standardization of Precordial Leads—Supplementary Report, Ibid. **110**: 681, 1938.
6. Wilson, F. N., Johnston, F. D., Macleod, A. G., and Barker, P. S.: Electrocardiograms That Represent the Potential Variations of a Single Electrode, AM. HEART J. **9**: 447, 1934.
7. Larsen, K. H.: Some Remarks on the Technique in Clinical Electrocardiography With Precordial Derivation, AM. HEART J. **14**: 1, 1937.
8. Larsen, K. H., and Warburg, E. J.: A Rational Principle for the Connections of the Leads of the Electrocardiograph in Clinical Electrocardiography With Precordial Derivation, AM. HEART J. **14**: 7, 1937.
9. Gilson, A. S., and Bishop, G. H.: The Effect of Remote Leads Upon the Form of the Recorded Electrocardiogram, Am. J. Physiol. **118**: 743, 1937.
10. Holzman, M.: Klinische Erfahrungen mit elektrokardiographischen Brustwandableitungen, Archiv für Kreislaufforschung, Band I, Heft 1-6, 1937.
11. Groedel, Franz M.: Das Extremitäten-, Thorax- und Partial-Electrocardiogramm des Menschen. Eine vergleichende Studie. 2 vol. Dresden und Leipzig, 1934, Theodor Steinkopff.
12. Katz, L. N., in collaboration with A. Bohning, I. Gutman, K. Jochim, H. Korey, F. Ocko, and M. Robinow: Concerning a New Concept of the Genesis of the Electrocardiogram, AM. HEART J. **13**: 17, 1937.
13. Wood, F. C., and Wolferth, C. C.: An Electrocardiographic Study of Experimental Coronary Occlusion: The Inadequacy of the Three Conventional Leads in Recording Certain Characteristic Changes in Action Current, J. Clin. Investigation **11**: 815, 1932.
14. Wood, F. C., Bellet, S., McMillan, T. M., and Wolferth, C. C.: Electrocardiographic Study of Coronary Occlusion: Further Observations on the Use of Chest Leads, Arch. Int. Med. **52**: 752, 1933.
15. Wood, F. C., and Wolferth, C. C.: Huge T-Waves in Precordial Leads in Cardiac Infarction, AM. HEART J. **9**: 706, 1934.

16. Levine, Louis: Chest Leads in Coronary Occlusion, M. J. and Rec. **136**: 421, 1932.
17. Hoffman, A. M., and Delong, E.: Standardization of Chest Leads and Their Value in Coronary Thrombosis and Myocardial Damage, Arch. Int. Med. **51**: 947, 1933.
18. Katz, L. N., and Kissin, M.: A Study of Lead IV, AM. HEART J. **8**: 595, 1933.
19. Bellet, S., and Johnston, C. G.: The Effect of Coronary Occlusion Upon the Initial Phase of the Ventricular Complex in Precordial Leads, J. Clin. Investigation **13**: 725, 1934.
20. Feinstein, Marcus A., and Lieberson, Abraham: Characteristic Serial Changes in the Fourth Lead After Acute Coronary Thrombosis, AM. HEART J. **14**: 69, 1937.
21. Bohning, A., and Katz, L. N.: Four Lead Elcetrocardiogram in Cases of Recent Coronary Occlusion, Arch. Int. Med. **61**: 241 and 519, 1938.
22. Lieberson, A., and Liberson, F.: The Value of the Posterior-Anterior Chest Leads in Cardiac Diagnosis, Ann. Int. Med. **6**: 1315, 1933.
23. Goldbloom, A. A.: Clinical Evaluation of Lead IV (Chest Leads). A Survey of Lead IV in Ambulatory Cases of Coronary Artery Disease and Acute Coronary Occlusion, Am. J. Med. Sci. **187**: 489, 1934.
24. Bohning, A., and Katz, L. N.: The Four Lead Electrocardiogram in Coronary Sclerosis, Am. J. Med. Sci. **189**: 833, 1935.
25. Levy, R. L., and Bruenn, H. G.: The Precordial Lead of the Electrocardiogram (Lead IV) as an Aid in the Recognition of Active Carditis in Rheumatic Fever, AM. HEART J. **10**: 881, 1935.
26. Levine, H. D., and Levine, S. A.: An Electrocardiographic Study of Lead IV With Special Reference to the Findings in Angina Pectoris, Am. J. Med. Sci. **191**: 98, 1936.
27. Van Nieuwenhuizen, C. L. C., and Hartog, H. A. P.: Chest Leads in Electrocardiography, Arch. Int. Med. **59**: 448, 1937.
28. Van Nieuwenhuizen, C. L. C., and Hartog, H. A. P.: The Electrocardiogram in Hypertension With Special Reference to Lead IV, AM. HEART J. **13**: 308, 1937.
29. Roth, Irving R.: Chest Lead Tracings in Arterial Hypertension With Cardiac Enlargement, AM. HEART J. **14**: 155, 1937.
30. Eckey, P., and Fröhlich, R.: Zur Frage der unipolaren Ableitung des Electrokardiogramms, Arch. f. Kreislaufforschung **2**: 349, 1938.
31. Eycleshymer, A. C., and Schoemaker, D. M.: A Cross Section Anatomy, New York & London, 1911, Appleton and Co.
32. Lindner, E., and Katz, L. N.: Am. J. Physiol. (in press).
33. Craib, W. H.: The Electrocardiogram. Special Report Series No. 147, Medical Research Council, 1930.
34. Abramson, D. I., and Jochim, K.: The Spread of the Impulse in the Mammalian Ventricle, Am. J. Physiol. **120**: 635, 1937.
35. Katz, L. N.: The Asynchronism of Right and Left Ventricular Contractions and the Independent Variations in Their Duration, Am. J. Physiol. **72**: 655, 1925.
36. Jochim, K., Katz, L. N., and Mayne, W.: The Monophasic Electrogram Obtained From the Mammalian Heart, Am. J. Physiol. **111**: 177, 1935.
37. Eyster, J. A. E., Maresh, F., and Krasno, M. R.: The Nature of the Electrical Field Around the Heart, Am. J. Physiol. **106**: 574, 1933.
38. Eyster, J. A. E., Maresh, F., and Krasno, M. R.: The Nature of the R Wave Potentials in the Tortoise and Frog Heart, Am. J. Physiol. **110**: 422, 1934.
39. Krasno, M. R., Eyster, J. A. E., and Maresh, C. A.: Nature of T Wave Potentials in Tortoise Heart, Am. J. Physiol. **114**: 119, 1935.
40. Schellong, F., Schwingel, E., and Hermann, G.: Die praktischklinische Methode der Vektordiagraphie und das normale Vektordiagramm, Arch. f. Kreislaufforschung **2**: 1, 1937.
41. Wilson, F. N., Macleod, A. G., and Barker, P. S.: The Order of Ventricular Excitation in Human Bundle-Branch Block, AM. HEART J. **7**: 305, 1932.
42. Brown, W. H.: A Study of the Esophageal Lead in Clinical Electrocardiography, AM. HEART J. **12**: 307, 1936.
43. Katz, L. N., and Korey, H.: The Manner in Which the Electric Currents Generated by the Heart Are Conducted Away, Am. J. Physiol. **111**: 83, 1935.
44. Robinow, M., Katz, L. N., and Bohning, A.: The Appearance of the T Wave in Lead IV in Normal Children and in Children With Rheumatic Heart Disease, AM. HEART J. **12**: 88, 1936.

THE EFFECT OF FEVER ON POSTURAL CHANGES IN BLOOD PRESSURE AND PULSE RATE*

ISRAEL KOPP, M.D.
BOSTON, MASS.

IN THE course of artificial fever therapy it has been observed that a change in the position of the patient from the recumbent to the sitting position resulted occasionally in marked weakness, fainting, and even unconsciousness and convulsions. It is a reasonable a priori assumption that this is due to a rapid and marked drop in the blood pressure caused by extensive vasodilation and faulty adjustment of the vasopressor mechanism to changes in body posture.

Ellis and Haynes[1] have reported that postural hypotension is more likely to occur in patients who have some disease of the central nervous system. As most of the patients receiving fever therapy in our clinic have neurologic disease, and as fever therapy causes considerable stress and strain on the cardiovascular system, it seems likely that the ability of the vasopressor system to adjust itself during and immediately following fever would be lessened. A study was therefore undertaken to determine the effect of postural change on the pulse rate and the systolic and diastolic blood pressures in the basal state, at the height of fever, and again as the temperature fell toward the normal level.

MATERIAL

Observations were made on forty patients, twenty-nine males and eleven females, whose ages varied from 17 to 52 years, with an average age of 39½ years. The patients received fever therapy for the following conditions:

1. Twenty-two patients—*general paresis.* In this group are included one patient with syphilitic aortic regurgitation, two patients with syphilitic aortitis, and one patient with a "funnel chest" and displacement of the heart to the left anterior axillary line.
2. Six patients—*meningovascular neurosyphilis.* In this group is included one patient with syphilitic aortitis.
3. Four patients—*tabes dorsalis.*
4. Six patients—*multiple sclerosis.*
5. One patient—*congenital syphilis and interstitial keratitis.*
6. One patient—*rheumatic heart disease and subacute arthritis* of undetermined etiology.

METHODS

With but few exceptions, all observations were made under fasting conditions. Following a rest period of from 30 to 45 minutes in the recumbent position, repeated blood pressure and pulse rate determinations were obtained during a period

*From the Boston Psychopathic Hospital, under the direction of Dr. Harry C. Solomon, Chief of Therapeutic Research.
Received for publication Nov. 17, 1938.

of 10 to 20 minutes before and after fever therapy, and over a shorter period of time when the temperature was at its maximum. After these observations were obtained in the recumbent position in each of the three phases, the patient was sat up, and readings were again obtained at intervals of 5, 30, 60, 120, and 180 seconds. The patient was then placed back in the recumbent position and readings obtained each minute thereafter for five consecutive minutes. These procedures were carried out when the body temperature was normal, following the administration of two to five hours of artificial fever at temperature levels ranging from 103° to 106.5°, and when the body temperature had fallen to, or close to, the basal level.

Fever was induced by means of diathermy or inductothermy combined with the lamp cabinet, the lamp cabinet alone, and the Kettering hypertherm.

RESULTS

Pulse Rate.—The pulse rate rose in all patients when the sitting position was assumed, both before and after the induction of fever, with the exception of two patients in whom a fall occurred at the height of the fever. The increase in pulse rate and the percentage change with the shift in posture were greatest when fever treatment was completed and body temperature had fallen to nearly basal levels (Fig. 1).

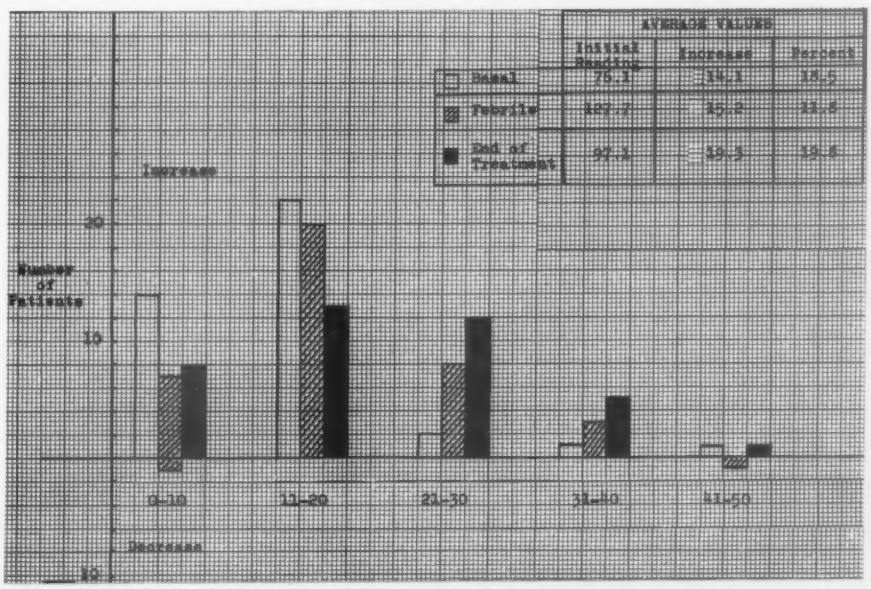


Fig. 1.—The effect of postural change on the pulse rate.

Systolic Blood Pressure.—As a result of the application of fever, the systolic blood pressure was likely to show an immediate and greater fall within 30 seconds after the change to the sitting position (Tables I and II). A compensatory rise in systolic pressure occurred less frequently under these conditions than before fever was induced. Whereas the systolic blood pressure showed a fall in only three patients when the sitting position was assumed under basal conditions, this occurred

TABLE I

EFFECT OF CHANGE OF POSTURE ON THE SYSTOLIC BLOOD PRESSURE UNDER BASAL CONDITIONS, DURING HYPERPYREXIA, AND AFTER THE TERMINATION OF FEVER TREATMENT

AVERAGE PRESSURE BEFORE TEST	RISE ONLY				RISE AND FALL				FALL ONLY			
	NO. PATIENTS	RANGE IN MM.	AVERAGE VALUES MAX.	MIN.	NO. PATIENTS	RANGE IN MM.	AVERAGE VALUES MAX.	MIN.	NO. PATIENTS	RANGE IN MM.	AVERAGE VALUES MAX.	MIN.
Basal 107.7 mm.	28	0-30	18.9	9.6	9	+20 to -14	+8.0	-7.0	3	- 2 to -18	-12.0	- 3.0
Febrile 100.5 mm.†	6	3-27	17.1	8.3	11	+16 to -13	+6.9	-6.4	23	0* to -53	-19.7	-11.0
End of Treatment 93.3 mm.	16	1-31	16.8	6.0	16	+17 to -21	+6.4	-8.3	7	- 1 to -42	-18.5	- 8.7

*Decrease of 180-195 mm. omitted.

†Reading of 300 mm. omitted in average.

TABLE II

MINIMUM SYSTOLIC PRESSURE LEVELS BEFORE AND AFTER THE CHANGE IN POSTURE*

	SYSTOLIC BLOOD PRESSURE		
	50-60 MM.	61-70 MM.	71-80 MM.
Before Treatment			
Recumbent	0	0	3
Sitting	0	0	1
At Height of Fever			
Recumbent	0	1	6
Sitting	4	2	9
End of Treatment			
Recumbent	0	2	4
Sitting	3	4	7

*The incidence of low systolic pressures is greater when the sitting position is assumed during and after the application of artificial fever.

in twenty-three patients at the height of the fever and in seven patients after body temperature had fallen. (It should be pointed out that the application of fever results in a lowering of the average systolic blood pressure.)

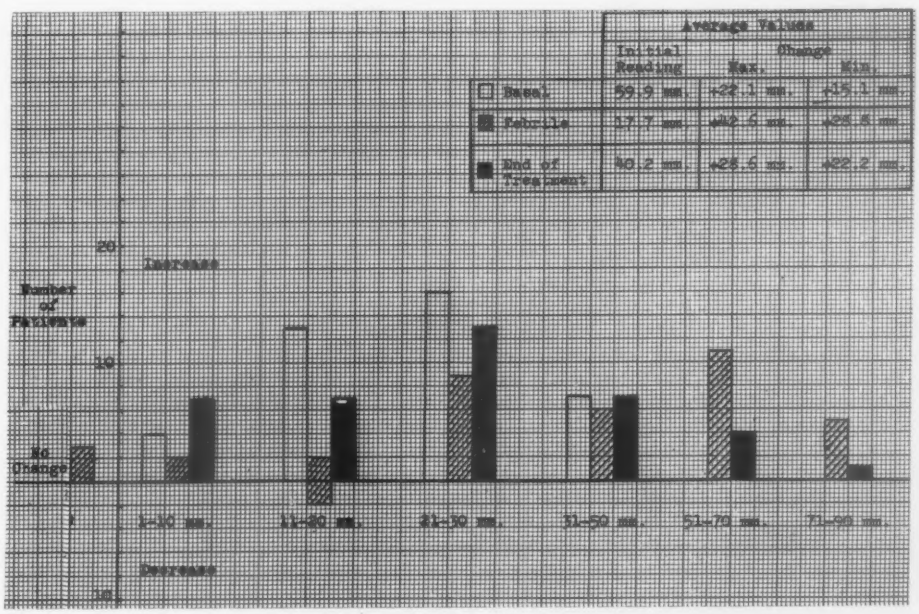


Fig. 2.—The effect of postural change on the diastolic pressure.

Diastolic Pressure.—In the basal state the change in position caused a rise in the diastolic pressure in all of the patients (Fig. 2). Both at the height of the fever and after the temperature had approached normal, the rise in diastolic pressure was greater and in some instances was quite marked. This was offset somewhat by the low diastolic pressure due to fever per se.

From these findings it becomes evident that in some patients during the febrile state, or immediately after the temperature has fallen, a change from the recumbent to the sitting position causes, as the most significant finding, a marked reduction in the pulse pressure due to a relatively small rise, no change, and, very often, a fall, in the systolic pressure, and a considerable rise in the diastolic pressure (Table III).

On resuming the supine position, from the sitting posture, the return of the blood pressure and pulse rate to the initial levels present before the test was applied was fairly prompt, occurring within two minutes in most patients under basal conditions, but taking more time after body temperature had fallen, and still more at the height of fever.

TABLE III

MINIMUM PULSE PRESSURE LEVELS BEFORE AND AFTER THE POSTURAL CHANGE*

	PULSE PRESSURE	
	6-9 MM.	10-15 MM.
Basal		
Recumbent	0	0
Sitting	0	3
Febrile		
Recumbent	0	0
Sitting	1	13
End of treatment		
Recumbent	0	0
Sitting	3	8

*Marked reductions in the pulse pressure are more frequent when the sitting position is assumed during and after the application of artificial fever.

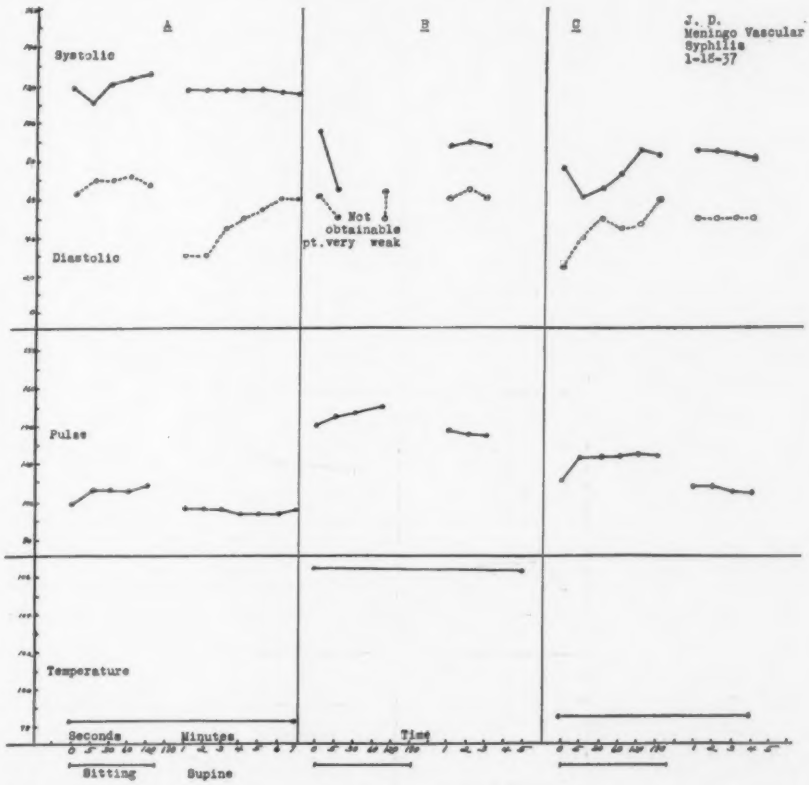
A division of the patients into two groups, those whose basal systolic blood pressures were above 120 mm. and below 100 mm. respectively, reveals that the initial systolic level was of little significance in the type of response obtained either at the height of the fever or after body temperature has fallen. A division of the patients with paresis into those having severe, intermediate, and mild degrees of the disease results in a similar conclusion. Though only four patients with tabes dorsalis are included in our series, it is our impression that adjustment to postural change was more difficult in these patients than in those with general paresis. As a group, the responses of the patients with multiple sclerosis to postural changes under the various conditions were good.

The increases in pulse rate in the individual patient with the change in posture were variable, tending to be greater at the height of the fever and greatest at the end of treatment. However, individual differences were present, the increases in some being about equal on each test or even less while body temperature was increased. In one male patient, 44 years of age, who was thought to have general paresis, a rather marked fall in pulse rate, from 136 to 87 beats, occurred with assumption of the sitting position when the rectal temperature was 106.2° F. The pulse rate rose to 126 while the sitting position was maintained for two and a half minutes, but did not reach the level present before the change in posture.

The changes in the systolic blood pressure in the individual patient were somewhat variable. However, those patients who exhibited both a rise and a fall, or a

fall alone, in the systolic pressure under basal conditions usually responded in a similar fashion, or showed a fall alone, at the height of the fever and at the end of treatment. It is evident also that other patients who responded with an increase in the systolic pressure under basal conditions showed a different response during and after fever, either fluctuations in both directions or reductions alone.

In two patients, J. D. (52 years old, meningovascular neurosyphilis), and C. A. (56 years old, tabes dorsalis), the change to the sitting position at the height of the fever was accompanied by changes in the blood pressure and the pulse rate characteristic of postural hypotension (Figs. 3 and 4).



Figs. 3 and 4.—The alterations in the blood pressure and pulse rate produced by changing to the sitting position at the height of the fever resemble those seen in postural hypotension. *A*, Before fever induction; *B*, at height of fever; *C*, at end of treatment.

In one patient (36 years old, multiple sclerosis), the initial systolic pressure in the supine position at a temperature of 104° F. before the test was carried out was 300 mm. on numerous occasions. The change to the sitting position resulted in a drop to 105 mm. The marked increase in the systolic pressure at the height of fever, at a time when there is usually a slight fall or rise in most patients, seems incredible, but the measurements obtained on five consecutive minute readings following the resumption of the recumbent position ranged from 210 mm. to 100 mm. (Observations on the blood pressure of a large group of patients given artificial fever by similar methods have revealed in a number of patients blood pressure values ranging from 240 mm. to 300 mm. over periods of one to two hours.)

DISCUSSION

Compensation is usually prompt and adequate with a change in body position. A change from the recumbent to the standing position in the normal person is accompanied by only slight fluctuations in the systolic pressure, usually less than 10 mm. in either direction, slight increases in the diastolic pressure, and only slight decreases in the pulse pressure. The heart rate may increase from 10 to 20 beats a minute.[1] These

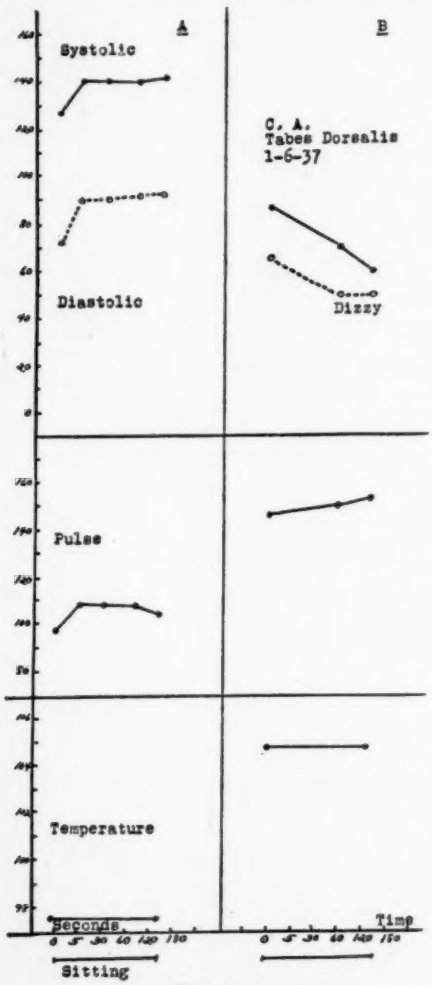


Fig. 4.

changes tend to overcome any pooling of blood in the areas below the level of the heart and to maintain an adequate blood supply to the brain. A diminution of the latter stimulates the vasomotor center, which sends out impulses constricting the arterioles. Of considerable importance in the adjustment to postural change is the vasoconstrictor action in the splanchnic area, which in man prevents a fall in blood pressure.[2]

Various types of inadequate responses to postural change occur. Adaptation may be insufficient immediately on the assumption of the upright position with subsequent full compensation, or compensation may be good but as the position is maintained adaptation becomes inadequate. In the latter case the systolic pressure falls steadily, the diastolic pressure remains the same or may increase slowly, and the heart rate continues to rise. The postural reflex may be delayed, as shown by an initial fall in the blood pressure, or it may respond with insufficient intensity. It may respond excessively, as shown by a rapid heart rate or by the maintenance or increase in the diastolic blood pressure.[1]

Changes in the systolic and diastolic blood pressures and pulse rate should be less pronounced when changing from the supine to the sitting position than from the supine to the standing position. Under basal conditions, the changes which occurred in our patients when the sitting position was assumed were often less marked than those found by others in patients changing to the erect posture. In some, however, the increases in pulse rate, systolic pressure, and especially the diastolic pressure, were much greater. The more marked increases in the pulse rate have been attributed to greater efforts on the part of the heart to maintain circulatory equilibrium.[3] In addition, individual variations in the responses of the pulse rate and blood pressure to postural change are considerable.[4]

From the results obtained in our patients it is evident that the ability to adapt to postural change is made more difficult by the induction of artificial fever, and that this difficulty persists even after body temperature has fallen to, or close to, its basal level.

Difficulties in adjusting to the change from the recumbent to the sitting position under these conditions are revealed by:

1. The greater incidence of an immediate or a sustained fall of the systolic blood pressure to low levels.
2. More frequent fluctuations in blood pressure above and below the initial level present in the supine position.
3. Inability to maintain an initial rise in systolic pressure.
4. A fall of diastolic pressure, or inability of the diastolic pressure to rise.
5. Greatly reduced pulse pressure.
6. Greater and progressive increases in the pulse rate.

Observers have attributed inadequate adaptation to postural changes to impairment of intrinsic vascular tone or poor tone in the skeletal musculature, especially of the abdomen and legs, resulting in pooling of the blood in the dependent areas (either because of poor venous tone or failure of the skeletal muscles to assist in venous return), insufficient

cardiac output, and cerebral anemia.[1] Difficulty in postural adaptation has been observed in patients convalescing from severe infections, debilitated patients, and in patients with vasomotor instability and the effort syndrome.[1]

Body musculature is considerably relaxed during and following artificial fever therapy and dehydration of a variable degree also frequently occurs,[5] both resulting in an inadequate venous return and a diminished cardiac output. The change from the supine to the sitting position reduces still further the cardiac output[6] and cerebral blood flow.[7]

Marked peripheral vasodilation is present as a result of artificially induced fever and, if long continued, capillary tone is impaired, with consequent stasis.[8] Visceral engorgement is marked and is intensified by gravity when the sitting position is assumed, diminishing still further the venous return. The long continued application of artificial fever may result in exhaustion of the sympathetic nervous system,[9] and since the responses of the vasomotor reflexes to postural change are mediated through the sympathetic nervous system,[1] they may become inadequate.

The prompt rise of the diastolic blood pressure in most of the patients when the sitting position was assumed during and following fever would seem to indicate that vascular tone was but slightly impaired as a result of fever. However, the inability of the systolic pressure to rise with the change in posture might well be due either to impaired vascular tone or to a diminished output for each heart beat.

The weakness, fainting, and convulsions which occurred in some of the patients as a result of the change to the sitting position, both at the height of fever and after body temperature had fallen, can be attributed, therefore, to diminution of the cerebral blood flow, not only as a result of the change in posture per se, but also because of the insufficient venous return due to dehydration, visceral engorgement, and possibly an impaired vasopressor mechanism. This is substantiated by the fact that when the sitting position was assumed at these times there were more frequently a fall in systolic blood pressure to low levels and a relatively large reduction in pulse pressure.

Similar alterations in response to changes in posture are said to occur as a result of anesthesia. Under chloroform, and to a less extent under ether and other anesthetics, also during shock and various unconscious states, the compensatory responses to changes from the horizontal position are depressed, and any change from this position may result in serious danger to life.[10] It has been shown that general anesthesia, narcotic drugs, injections of histamine or barbiturates, severe anoxemia, and pulmonary hyperventilation will often depress considerably, or even abolish, the pressoreceptive regulation of the blood pressure and the circulation.[11] It has also been shown that the administration of vasodilator drugs, such as histamine and sodium nitrite, destroys the normal

compensatory reactions of the vasomotor system when there is a change from the horizontal to the upright position.[12] It is quite possible that artificial fever, as induced under the above conditions, may have a similar effect.

The fact that no symptoms and no abnormal responses were noted in some patients did not eliminate the possibility of an abnormal response when the patient was allowed to walk or stand. Patient D., though she responded in what appeared to be a normal manner to the tests applied, experienced a series of convulsive seizures when allowed to walk to the balance for a weight determination at the end of treatment. Patient C. A. had a convulsion when he attempted to stand following his treatment. Though muscular movements result in a greater venous return, the demands made upon the vasopressor and cardiovascular mechanisms when standing or walking following fever therapy are much greater than when changing from the supine to the sitting position, and inadequate responses, with symptoms, are more apt to occur.

The responses in blood pressure and pulse rate occurring in some of the patients at the end of treatment, when body temperature was nearly normal, were even more abnormal than those obtained at the height of the fever, indicating that residuals of the stress upon the cardiovascular and nervous systems are still present even when treatment has been completed.

The presence of heart disease due to syphilis or rheumatic fever in five of our patients did not appear to influence the results obtained in these patients, since the responses did not differ in any way from those which occurred in the patients without cardiac disease. There were, however, no signs of myocardial insufficiency in these five patients.

Our findings appear also to corroborate the statements of other workers[1, 7] that dizziness and fainting are most likely to occur with postural change when other factors promoting cerebral anemia, such as arteriosclerosis, are present, for in our series symptoms were most prominent in patients above 50 years of age. However, an initially low blood pressure did not play as important a role and did not appear to bear any relationship to difficulties in adaptation, either before, during, or after the application of fever. Untoward symptoms did not result in all patients whose systolic blood pressure had fallen to low levels in the sitting position, indicating that there was no absolute level at which difficulties would occur.

It was interesting that some of the patients, when placed in the sitting position during fever and after body temperature had fallen, had excessive sweating over the face and shoulders, accompanied by pallor and very little sweating over the remainder of the body. In others the change in posture under these conditions was followed by dyspnea, eructations of gas, restlessness, nausea, weakness, dizziness, or blurring of vision.

SUMMARY

1. Studies were carried out to determine the effect of artificial fever upon the responses of the blood pressure and pulse rate to changes in body posture.

2. The application of artificial fever results in a greater frequency of inadequate responses to postural change, more marked at the height of the fever than when body temperature has fallen.

3. Inability of the postural vasomotor reflex to respond in a normal manner under these conditions is revealed especially by the more frequent immediate and sustained drop in the systolic blood pressure, and by rather marked reductions in pulse pressure.

4. Untoward reactions, such as fainting, unconsciousness, and convulsions, brought on by changes in body posture during or after the induction of artificial fever, are due to cerebral anemia caused by a diminished cardiac output and an impaired vasopressor mechanism.

REFERENCES

1. Ellis, L. B., and Haynes, F. W.: Postural Hypotension With Particular Reference to Its Occurrence in Disease of the Central Nervous System, Arch. Int. Med. **58:** 773, 1936.
2. Roth, G. M.: The Postural Effects on Blood Pressure Following Interruption of the Vasomotor Nerves of Man, AM. HEART J. **14:** 87, 1937.
3. Mortensen, M. A.: Blood Pressure Reactions to Passive Postural Changes. An Index to Myocardial Efficiency, Am. J. Med. Sc. **165:** 667, 1923.
4. Ghrist, D. G.: Variations in Pulse and Blood Pressure With Interrupted Change of Posture, Ann. Int. Med. **4:** 945, 1931.
5. Gibson, J. G. 2nd, and Kopp, I.: Studies in the Physiology of Artificial Fever I. Changes in the Blood Volume and Water Balance, J. Clin. Investigation **17:** 219, 1938.
6. McMichael, John: Postural Changes in Cardiac Output and Respiration in Man, Quart. J. Exper. Physiol. **27:** 55, 1937.
7. Loman, J., and Myerson, A.: Studies in the Dynamics of the Human Cranio-Vertebral Cavity, Am. J. Psychiat. **92:** 791, 1936.
8. Krogh, A.: The Anatomy and Physiology of Capillaries, New Haven, 1924, Yale University Press, pp. 232 & 235.
9. Kopp, I., and Solomon, H. C.: Shock Syndrome in Therapeutic Hyperpyrexia, Arch. Int. Med. **60:** 597, 1937.
10. Best, C. H., and Taylor, N. B.: Physiological Basis of Medical Practice, Baltimore, 1937, William Wood and Company, p. 220.
11. Heymans, C.: The Pressoreceptive Mechanisms for the Regulation of Heart Rate, Vasomotor Tone, Blood Pressure and Blood Supply, New England J. Med. **219:** 147, 1938.
12. Loman, J., Dameshek, W., Myerson, A., and Goldman, D.: Effect of Alterations in Posture on the Intra-Arterial Blood Pressure in Man. II. Pressure in the Carotid Artery in Arterio-Sclerosis, During Syncope and After the Use of Vasodilator Drugs, Arch. Neurol. & Psychiat. **35:** 1225, 1936.

EMBOLISM AND THROMBOSIS OF THE ABDOMINAL AORTA

Report of Three Unusual Cases

Franklin W. Fry, M.D.
Hempstead, N. Y.

THERE have appeared in the recent medical literature reports of approximately 135 cases of embolism and thrombosis of the abdominal aorta, of which 125 were ably abstracted by Rothstein,[1] in 1935. Of the 135 patients, only twenty survived, ten by virtue of the development of an adequate collateral circulation, as reported by Gull and Chvostek,[2a] Nunez,[2b] Derman and Dutkewitsch,[3] van der Beek,[4] Bull,[5] and Rykert and Graham.[6] One recovered spontaneously and two improved under treatment with alternating suction and pressure. In one case reported by Rothstein the patient recovered, probably because the embolus passed from the bifurcation of the aorta into the iliac artery. The remaining nine patients were relieved by embolectomy. Death was usually not long delayed, following close upon gangrene of one or both legs. In Hesse's[7] series of forty-six cases, the duration of life after the onset of embolic symptoms was as follows: nine patients died within twenty-four hours, six more within forty-eight hours, a total of twenty-four within one week, a total of thirty-five in the first month, and the remaining eleven patients all died between the second and sixth month. In the three cases presented in this article death occurred from twelve months to five years after the initial embolic symptoms. In two of the three there was no evidence of gangrene, and the immediate cause of death was intercurrent disease.

In contradistinction to embolism of the abdominal aorta, which is characterized by dramatic, sudden onset, as illustrated by Welch,[8] primary thrombosis of this artery may be ushered in by slight, easily mistaken, or overlooked symptoms. In the majority of cases there is a primary embolus, followed by retrograde thrombosis of the involved artery. In these latter cases the classical sign of gangrene of an extremity may be late or entirely absent, depending on the speed of extension of the occluding thrombus up the vessel. Bull,[5] however, states that the presence or absence of gangrene depends upon whether the lumen is completely or partially occluded.

To illustrate a marked degree of occlusion of the aorta with a minimum of symptoms of arterial obstruction, three cases of complete thrombosis of the abdominal aorta are presented in some detail.

REPORT OF CASES

Case 1.—W. O., a 21-year-old grocer's clerk, was admitted to the North Country Communities Hospital, Glen Cove, L. I., on three occasions over a three-year period.

Received for publication Nov. 18, 1938.

He was first admitted April 2, 1933, with the history that two weeks prior to admission he had been forced to cease work because of tightness of the muscles of the left arm and of the calves of his legs. This condition was aggravated by exertion and relieved by sitting or lying down. Aside from the pain, the patient had noted no abnormality in either arms or legs. Two days before admission he was awakened in the night with a severe pain in his upper abdomen which was associated with nausea and vomiting. The pain and vomiting persisted the following day, and he was hospitalized for this complaint.

The family, past, and personal histories were entirely negative. The patient was a moderate user of tobacco.

The examination on admission revealed that the patient was a fairly well-nourished white man, not cyanotic or dyspneic. The blood pressure in the right arm was 130/78; in the left arm it could not be measured. No pulse was perceptible in the left arm. Whether or not there were pulsations in the femoral arteries was not ascertained. The heart sounds were normal. The abdomen was scaphoid and showed no localized tenderness or rigidity. Bilateral costovertebral tenderness was present, more pronounced on the right side than on the left. The extremities were normal.

Laboratory Examination.—The urine was normal. The hemoglobin was 88 per cent, the erythrocyte count 4,550,000, and the leucocyte count 9,500; 75 per cent of the leucocytes were polymorphonuclear cells. The blood Wassermann reaction was negative.

A roentgenologic examination of the chest failed to reveal any evidence of disease. Cholecystograms were reported as showing normal gall bladder function.

The patient remained in the hospital for eight days, during which time gradual improvement was noted. During the first three days of the hospital stay he continued to complain of vague abdominal pain. At no time were there any complaints referable to the legs, and no objective signs were found in the lower extremities.

The patient was next admitted to the hospital Jan. 24, 1934, approximately ten months after his first admission, with the history that his legs had become too weak to permit him to carry on his previous work as a grocer's clerk. He had also noticed that they became painful on walking. The pain and weakness had been noticed in lesser degree in the arms. He complained that his feet became cold more easily, and that epicritic sensation in the feet was diminished. "Ace" bandages applied to the legs had caused intolerable pain. About seven months before this second admission, the patient began having transient attacks of diplopia; this symptom had become more severe within the preceding week and had necessitated the second admission.

The examination on this admission revealed, in addition to the previous findings, that the heart was slightly enlarged to the left. A systolic thrill was felt at the apex. The pulmonic second sound was louder than the aortic second sound. There was a presystolic rumble at the apex. The blood pressure in the right arm was 140/80. No attempt was made to measure the blood pressure in the left arm. The neurologic examination revealed evidence of ataxia, as demonstrated by a positive Romberg test. A general weakness of the lower extremities was noted, and a slight involvement of the right seventh nerve and right third nerve nucleus, as evidenced by irregular pupils and ptosis of the left lid, was observed.

Laboratory examination again showed a normal urine and a normal blood count. A spinal puncture revealed that the spinal fluid was under normal pressure and contained the normal number of cells. While in the hospital the diplopia disappeared and the ataxia improved, so that the patient was discharged eleven days after admission with a tentative diagnosis of encephalitis.

The patient was next seen in the hospital twenty-three months later, Nov. 24, 1935. He said that for the preceding four days he had been short of breath. A cough which had been present for approximately one week had become worse and productive of bloody sputum, and was associated with pain in the anterior portion of the left chest. Hospitalization was advised when a marked pericardial friction rub was heard by his physician.

The interval history was otherwise negative except for the continued presence of intermittent claudication. There had been no diminution in cardiac reserve noted during the preceding two years.

The physical examination on this admission showed a dyspneic, pale, acutely ill, thin young man. Slight cyanosis and orthopnea were present. The pupils were slightly irregular but reacted normally to light and in accommodation. Evidence of marked hypertrophy of the left side of the heart was found; the lower outermost point of the apical impulse was in the sixth intercostal space, 14 cm. from the midsternal line. At the apex of the heart a marked pericardial friction rub was heard and gallop rhythm was present. There were a rough systolic and a high pitched diastolic murmur both at the apex and base of the heart. The blood pressure in the right arm was 190/100, and in the left arm 144/100. The blood pressure could not be measured in either leg. The lungs were dull to percussion, and there were moist râles at both bases. The liver was palpable below the costal border. It was not tender. Through the thin abdominal wall no pulsation of the abdominal aorta could be felt. It was noted that the femoral pulse on the right side was very weak, while no pulsation could be felt on the left. The extremities were otherwise normal.

The electrocardiogram showed sinus tachycardia, right axis deviation, and an auriculoventricular conduction time of .14 sec. The T wave was inverted in Leads I and II, and varied in Lead III. The precordial leads showed evidence of pericardial effusion, with depression of the ST segments in precordial Leads III and IV (method of Wilson, with the right arm lead wire connected to the exploring electrode).

Laboratory Examination.—On admission, the urine showed a very faint trace of albumin and three red blood cells to the high-power field. Red blood cells were not found on subsequent urine examinations, but granular casts appeared shortly before death. The hemoglobin was 62 per cent, the erythrocyte count 3,650,000, and the leucocyte count 9,000, of which 74 per cent were polymorphonuclear cells. The urea nitrogen content of the blood was 42 mg. per cent. The blood sugar and creatinine values were 150 and 2.2 mg. per cent, respectively. The blood culture on several occasions was sterile.

Roentgenologic examination of the chest at the time of admission showed a large pericardial effusion and soft, scattered pulmonary lesions suggesting lobular pneumonia. The findings were more marked in the central portion of the left lung.

The patient's condition grew steadily worse. The leucocytes gradually rose to 23,000, of which 84 per cent were polymorphonuclear cells. For the first few days the pericardial effusion was the predominant lesion. The friction rub remained for forty-eight hours. However, when fluids were forced the azotemia diminished, and within two weeks the pericardial effusion had disappeared. The gallop rhythm at the apex of the heart persisted. The veins of the neck remained distended throughout the entire hospital stay. Five days after admission the patient developed signs of fluid in the right side of the chest, and edema of the ankles which was more marked on the left side than on the right; the dyspnea and cyanosis increased, and the liver became palpable ten centimeters below the costal border. The patient was fully digitalized without effect. The orthopnea became more marked and the edema of the legs increased. The patient lapsed into semicoma and expired sixteen days after admission. The total duration of the illness had been thirty-three months.

The pertinent autopsy findings were as follows: Upon opening the thoracic cavity 2,000 c.c. of bloody fluid were found in the right pleural sac, pressing the right lung to the mediastinum. Both lungs were riddled with infarcts of various sizes.

The lining of the pericardium was smooth and glistening throughout, with no areas of roughening or inflammation. Fifty cubic centimeters of pericardial fluid were present. The heart weighed 500 gm. The right auricle was normal. Enmeshed in the normal chordae of the tricuspid valve were found two large, extremely friable thrombi; the smaller one measured 1 cm., and the larger, 2 cm., in diameter. The right ventricle and pulmonary valve were normal. The aortic valve was bicuspid, and the cusps were found to be thickened, producing a hard, roughened, ragged, inelastic valve. At the tip of the larger (posterior) cusp there were very small, friable, well-organized vegetations. The wall of the left ventricle was markedly hypertrophied. The mitral valve and left auricle were normal.

The liver weighed 1,735 gm., and the cut section of this organ showed chronic passive congestion. The gall bladder was large and distended; the walls were normal. A large, gray, friable thrombus was noticed at the junction of the hepatic vein and inferior vena cava.

The spleen was small, shrunken, and of the fetal type.

The pancreas was normal.

The right kidney was large, of the fetal type, and weighed 217 gm.; this kidney was anomalous in that the main renal artery originated 2 cm. higher than the left renal artery. The left kidney was small, weighing 70 gm.; on section, the normal striations were lost, and the organ was of a darker hue than its fellow.

The arch of the aorta was normal. The intercostal arteries, especially over the lower half of the thorax, were slightly dilated. The thoracic aorta was not dilated, but showed more evidence of arteriosclerosis than is normal for a man 21 years old. Just below the diaphragm the aorta was occluded by an old, organized thrombus, covered with endothelium. Between the apex of the thrombus and its base, the right renal artery, which was entirely patent, was found. One centimeter below this artery was the celiac axis, which was completely occluded by thrombus. Below the celiac axis was the left renal artery, which was found to be partially occluded. Immediately below the left renal artery the aorta shrank to a diameter of 2 cm. Both of the common iliac arteries were thrombosed throughout their entire diameter (Fig. 1). The thrombus in the aorta and iliac vessels was identified as old and well organized. A collateral circulation had been established, in part, between the deep epigastric and internal pudendal arteries.

Microscopic examination of the aortic cusps showed that the bicuspid condition was of congenital rather than inflammatory origin, as demonstrated by Bishop,[9] et al., with the Weigert elastic fiber stain, using the technique of Lewis and Grant.[10]

Microscopic study of the aorta revealed severe sclerotic changes of the intima and media, with laminated fibrinous thrombus filling the lumen. The lesions could not be identified by the pathologist as either syphilitic or rheumatic.

CASE 2.—V. T., a housewife, 42 years of age, was admitted to the Nassau Hospital, Mineola, L. I., in November, 1937, following a cerebral accident. The family history was negative. A history of rheumatic heart disease of two and a half years' standing was obtained. Eighteen months prior to admission she had had an infarct of the lung, with a slow recovery. Five months later an embolus had lodged in the left leg. This diagnosis was made because of coldness, pallor, and pain in the leg and foot, with inability to move the member. Within four months partial

function had returned. Residual weakness and intermittent claudication were the only remaining symptoms. There was no involvement of the bladder.

Physical examination of the patient on admission showed a dyspneic and orthopneic middle-aged woman. There was evidence of upper motor neurone paralysis of the left side. The heart was enlarged; the lower outermost point of the apical impulse was felt outside the midclavicular line. There were a systolic and diastolic murmur at the apex and a systolic murmur at the base. The ventricular rate was 100, the pulse rate 90. The blood pressure was 198/96. The spleen was not palpable. The liver was felt at the costal margin. The extremities were apparently normal. No discoloration was noted and the temperature of the legs was the same. There was no edema. Whether or not femoral artery pulsations were present was not ascertained.

Fig. 1.—Thrombosis of the abdominal aorta extending above the celiac axis (Case 1).

Laboratory Examinations.—The electrocardiogram showed auricular fibrillation. The urine was normal except for a faint trace of albumin and a few granular casts and leucocytes. The hemoglobin was 92 per cent and the erythrocyte count 5,360,000; the leucocytes numbered 20,400, of which 78 per cent were polymorphonuclear cells. The blood culture was sterile on two occasions. The blood Wassermann reaction was negative.

The patient remained in a state of semicoma and delirium, dying on the twenty-third hospital day with a rising ventricular rate and body temperature. The

paralysis remained unchanged. No circulatory changes were noted in the extremities throughout the entire period of hospitalization.

At autopsy there was a zone of softening, 6 cm. in diameter, in the right cerebral hemisphere, impinging on the lateral ventricle. The heart showed a right ventricle three times the normal thickness, a moderately thickened left ventricle, and an extremely stenotic mitral valve. On the posterior leaflet of the mitral valve there were numerous, red, calcific granulations. There was an adherent thrombus in the left auricle. The aorta in the upper portion was normal for the age of the patient. At the level immediately below the origin of the renal arteries the lumen of the aorta was occluded by a soft, red, but adherent, thrombus. This thrombus became firmer and more densely attached to the intima of the aorta as the bifurcation was approached. At this level the process was well organized. The contents of the lumen were yellowish gray and appeared partly fibrous. The process continued uninterrupted into the common iliac arteries.

The lungs showed diffuse congestion, but there was no evidence of pneumonia. The pleurae were covered by fibrous tissue; there was a small amount of fluid in both pleural spaces, from which the Type I pneumococcus was cultured. The spleen weighed 400 gm. and was grossly normal. The kidneys showed evidences of old infarction. The other organs were essentially normal.

Microscopic examination of the heart failed to show typical Aschoff bodies. There were, however, numerous foci of dense fibrous tissue around the blood vessels of the heart muscle.

Sections taken from that part of the aorta which was completely thrombosed showed the lumen with red thrombus adherent to the intima. Here the endothelium was deficient. The great part of the change lay in the media, where there were diffuse engorgement and reduplication of the small vessels and widespread infiltration of these tissues by polymorphonuclear cells and phagocytes containing hemosiderin.

The final diagnoses were rheumatic heart disease with mitral stenosis; mural thrombus of the left auricle; infarction of the right cerebrum; multiple old infarcts of the kidneys; acute fibrous and purulent pleuritis; diffuse mesaortitis; and endaortitis with thrombosis.

The autopsy findings were a surprise, for thrombosis of the aorta in this case was not suspected because of the paucity of symptoms referable to the abdomen and legs.

CASE 3.—H. B., a 54-year-old man whose mother had had hypertension, gave a past history which was essentially negative except for excessive cigarette smoking for many years.

The present illness began five years previously, when the patient noted a sudden pain in the left leg which was localized to the foot and calf and was associated with coldness of that member. This condition kept the patient in bed for three months, during which time there was improvement with the use of Buerger's exercises. Thereafter the patient's only symptoms had been intermittent claudication and partial loss of epicritic sensation of the left leg until three years prior to admission, when he had a similar attack with gangrene and loss of a small portion of the medial side of the left great toe. The toe later regenerated completely. He was subsequently treated by the Pavaex method, but noticed no lessening of the intermittent claudication. Fifteen months earlier he had had coronary occlusion, recovery from which was postponed by lobar pneumonia, the type and site of which were unknown to the patient. This occlusion was followed by a bilateral deep phlebitis of the legs and a subsequent pulmonary embolus. Still later there occurred an attack characterized by severe abdominal distention and hiccough which was diagnosed as mesenteric thrombosis. All these events took place over a ten-month period, during which the patient

was in a hospital in Canada practically the entire time. However, during the preceding four months he had been able to carry on his usual sedentary work as a writer, with no symptoms except intermittent claudication in both legs, worse on the left than on the right. There had been a loss of epicritic sensation in both feet. He had continued to smoke twenty to forty cigarettes a day until his admission to the Naussau Hospital. Two weeks prior to admission, following a great deal of walking, he noticed early gangrene of the third, fourth, and fifth toes of the left foot.

Examination on admission to the Nassau Hospital on March 22, 1938, showed a tall, spare, middle-aged man looking older than his years. The pupils were unequal, the right being larger than the left, but both reacted normally to light and in accommodation. Examination of the eye grounds showed moderate arteriosclerotic changes in the vessels. The cervical veins were not distended. The right lung was normal, but a few moist râles were heard at the base of the left lung. The heart was normal in size. The heart sounds were of fair quality at the apex and the base. There was a systolic murmur at the apex. The blood pressure in both arms was 136/80. The blood pressure could not be measured in either leg. The cardiac mechanism was normal, and the rate was 110 beats a minute. Neither the liver nor spleen was felt. The abdominal aorta was palpable through the thin abdominal wall down to the level of the umbilicus, where the pulsation abruptly ceased. There was marked sclerosis of the brachial and radial arteries. There was a very poor femoral pulsation on the right side, but a fair pulsation of the left femoral artery was felt. No dorsalis pedis or posterior tibial pulsation was noted in either leg. There was dry gangrene of the left third, fourth, and fifth toes, with regional cellulitis extending to the ankle. The temperature of the legs was the same. The veins were prominent, but no varicosities were present.

An electrocardiogram taken prior to admission showed changes typical of an old anterior wall infarction.

Laboratory Examination.—The specific gravity of the urine was 1.020; the urine contained no albumin or sugar. The blood Wassermann reaction was negative.

The patient's course in the hospital was characterized by slowly increasing dry gangrene of the entire left foot below the ankle, and by a sudden arterial occlusion in the right leg. This occlusion occurred seven days after admission, and resulted in a spreading dry gangrene of the right leg extending to mid-thigh. The patient was given the usual conservative treatment for gangrene, including alcohol by mouth, papaverine, tissue extract, generalized infrared light, and partially occlusive bandages to the leg. All treatment was to no avail. He became increasingly stuporous and "toxic" and had slight fever until the final week, when the temperature rose much higher. Death occurred suddenly eleven weeks after admission.

The pertinent autopsy findings were as follows: External examination showed dry gangrene of the left leg below the ankle and of the right leg below mid-thigh.

The lungs showed diffuse congestion. The heart weighed 375 gm. There was a definite increase in thickness of the wall of the left ventricle. Moderate generalized coronary sclerosis was present. The left descending coronary artery was found to be occluded and fibrosed by an old thrombus. At the apex of the left ventricle there was a large area of fibrosis, with an old, adherent, organized mural thrombus. There was no deformity of the valves. The heart was otherwise normal.

The arch and thoracic portion of the aorta were normal, showing only slight evidence of arteriosclerosis. There was no dilatation of the thoracic aorta and little increase in the diameter of the intercostal arteries. At the level of the

left renal artery the lumen of the aorta was completely obstructed by an organized thrombus, with a soft, fresh extension into the superior mesenteric artery. The right renal artery was patent, the left renal artery partially occluded. The thrombus continued into the common iliac arteries. The left iliac artery contained an old, white, organized thrombus, and the right iliac artery was obliterated by a more recent, red, fibrinous thrombus (Fig. 2). There was very little evidence of collateral circulation.

The upper pole of the left kidney was scarred by a large infarct which showed various stages of healing. The right kidney was normal.

The liver and spleen were grossly normal.

There was no evidence of gangrene or necrosis of the intestines.

Microscopic study of the thrombus at the level of the renal artery showed organization and no evidence of recanalization. The endothelial lining of the aorta was destroyed; the elastic layers were reduplicated, as demonstrated by the Weigert stain.

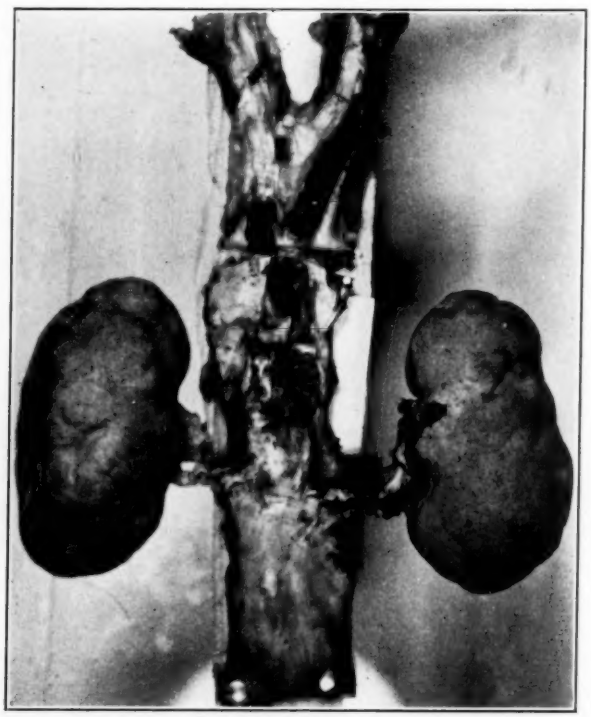


Fig. 2.—Two stages of thrombosis of abdominal aorta to the level of the renal arteries (Case 3).

COMMENT

It is interesting to compare the symptoms in these three cases with those in Rothstein's series of seventy-two cases (Table I). It is surprising, in view of the high extent of the thrombus in all three cases, and the organization present at the high level in two of these, that abdominal symptoms were not more marked and that spinal cord and bladder symptoms were not present in any case. The symptoms

in all three cases were caused by slowly decreasing blood supply. It is interesting to note that in two of the cases the abdominal aorta was found to be abnormal before death. This observation alone served to indicate the high extent of the lesions.

TABLE I

SYMPTOMATOLOGY OF OCCLUSION OF THE AORTA IN ROTHSTEIN'S[1] 72 CASES COMPARED WITH THAT IN THE 3 CASES HERE REPORTED

A. MANIFESTATIONS IN LOWER EXTERMITIES	PER CENT	CASES 1	2	3
1. Pain in legs	44.4	+	+	+
2. Loss of pulsation in arteries of lower extremities	40.3	+	?	+
3. Cyanosis or discoloration of lower extremities	22.2	0	0	+
4. Edema of lower extremities	6.9	+	0	0
5. Disturbances in sensation of lower extremities	40.3	+	+	+
6. Disturbances of muscle power of lower extremities	39.0	+	+	+
7. Preceding embolic phenomena in peripheral arteries of lower extremities	2.8	0	+	+
8. Intermittent limping	2.8	+	+	+
9. Disturbances in circulation beginning in one, and then in the other, extremity	16.6	+	+	+
10. Evidences of gangrene in lower extremities	57.0	0	0	+
a. Involving only the right lower extremity	12.5			
b. Involving only the left lower extremity	19.4			
c. One lower extremity (side not noted)	1.4			
d. Involving both lower extremities	23.7			+
B. MANIFESTATIONS OF INVOLVEMENT OF ABDOMINAL ORGANS	**PER CENT**	**CASES 1**	**2**	**3**
1. Pain in the abdomen	11.1	+	0	+
2. Pain in the back	5.5	+	0	+
3. Loss of pulsation of abdominal aorta	6.9	+	?	+
4. Incontinence of urine	6.9	0	0	0
5. Retention of urine	2.8	0	0	0
6. Incontinence of flatus	4.2	0	0	0
7. Hemorrhage from anus and urethra	8.3	0	0	0

Presence or absence of symptoms indicated by + or 0.

The fundamental lesions in all of these cases were different, but all led to the same terminal condition in the aorta and iliac arteries. As is noticed from the description in the microscopic reports, the endothelial wall of the aorta around the thrombus was destroyed in all cases. It is impossible to differentiate primary infection of the arterial wall from nonspecific reaction in cases of complete obstruction of long duration. In Case 1, the congenitally bicuspid aortic valve with roughening and organized small vegetations may have been a nidus for small emboli. No doubt the cerebral signs in this case were embolic. The symptomatology and course in this case were essentially that of progressive thrombosis superimposed upon small emboli. The long duration of life was possible only because of the anomalously high origin of the right renal

artery. In the second case, a mural thrombus in the fibrillating left auricle was the source of emboli, again with progressive superimposed thrombosis. In the third case the etiology was atherosclerosis, and the case was somewhat similar to one reported by Rosenberg,[11] et al. The use of the Weigert elastic stain was helpful in demonstrating the reduplication of the elastic fibers found in atherosclerosis.

CONCLUSION

Three cases of embolism and complete thrombosis of the abdominal aorta are reported; the fundamental lesions were etiologically different, but they all produced practically identical gross and microscopic changes in the aorta. The patients survived from one to five years after the onset of occlusive symptoms. Two of the three patients showed no evidence of gangrene in spite of the high level of the lesions.

These cases are reported to demonstrate, in addition to the unusual and widespread lesions, the ability of the circulatory system to adapt itself to a gradually occluding process, and to emphasize the fact that extensive pathologic changes may occur in the large vessels of the body with only minor symptoms.

REFERENCES

1. Rothstein, Jacob L.: Embolism and Thrombosis of the Abdominal Aorta in Infancy and in Childhood, Am. J. Dis. Child. **49:** 1578, 1935.
2a. Gull and Chvostek: Wiener Med. Blätter, p. 1513, 1881.
2b. Nunez: Gaz. Med. de la Habana II, p. 160, 1879-80, quoted by Welch (reference 8).
3. Derman, G. L., and Dutkewitsch, E. A.: Zur Frage des vollständigen Verschlusses des unteren Teiles der Bauchaorta, Virchow's Arch. f. path. Anat. **274:** 535, 1929-30.
4. van der Beek: Een geval van thrombose van de binkaorta, Nederl. tijdschr. v. geneesk. **76:** 4538, 1932.
5. Bull, P.: Hvad kan over 6000 Obduktioner lare os om embolia resp. gangraena embolica extremitatium? Norsk. mag. f. laegevidensk. **83:** 173, 1922.
6. Rykert, H., and Graham, D.: Some Problems in the Diagnosis, Prognosis and Treatment of Acute Arterial Occlusion, AM. HEART J. **15:** 395, 1938.
7. Hesse, E.: Ueber die Embolie und Thrombose der Aorta abdominalis und ihre operative Behandlung, Arch. f. klin. Chir. **115:** 812, 1921.
8. Welch, W.: Embolism and Thrombosis, In Albutt, I. C., and Rolleston, H. D.: System of Medicine, New York, vol. 6, p. 809, 1909, The Macmillan Company.
9. Bishop, Louis Faugeres, Bishop, Louis Faugeres, Jr., and Trubeck, Max: Aortic Stenosis of Inflammatory Origin With a Differential Study of the Acquired or Congenital Origin of a Bicuspid Aortic Valve, Am. J. M. Sc. **188:** 506, 1934.
10. Lewis, T., and Grant, R. T.: Heart **10:** 21, 1923.
11. Rosenberg, E. T., Keith, M. M., Wagener, H. P.: Diffuse Arterial Disease With Hypertension, Arch. Int. Med. **62:** 461, 1938.

DISSECTING ANEURYSM OF THE AORTA

HOBART ROGERS, M.D.
OAKLAND, CALIF.

ALTHOUGH a mechanism by which dissecting aneurysm of the aorta may occur has been understood for more than 200 years,[1] the clinical diagnosis has, until recently, rarely been made. In 1856 the first account of a correct ante-mortem diagnosis was published by Swaine.[2] In an extensive review of the literature in 1933, Shennan[3] accepted six ante-mortem diagnoses in 297 cases described. I have been able to find accounts of 24 additional cases[4] in which the ante-mortem diagnosis was anatomically demonstrated to be correct. This figure does not include the case of Keinbock and Weiss,[5] which seems convincing, but in which the diagnosis of the type of aneurysm rested solely on roentgenographic findings, nor does it include diagnoses unsupported by published details. The diagnosis has doubtless been correctly made in several instances which remain unreported.

This marked increase in the number of cases recognized has not been due to the development of any new diagnostic test or procedure, but is attributable solely to the increasing familiarity of alert practitioners with the clinical features of the condition. These features usually include a pre-existing hypertension. Syphilis is infrequently present. Most of the cases have occurred in males between forty and sixty years of age. The onset is usually sudden, often following some exertion or strain, with agonizing pain of a rending character, the location of which varies with the site of the aneurysm, but which characteristically exhibits a migratory tendency. It may begin anteriorly in the precordial region or in the epigastrium, pass to the neck or jaw, later to the back, the flanks, and the legs, or any of these areas may be involved. Radiation to the arms is less common than in myocardial infarction. The onset is also usually attended by pallor, perspiration, and prostration, and often by loss of consciousness. In some cases, however, pain is either absent or relatively insignificant. Once the aneurysm is formed, the symptoms are determined by the location and extent of the dissection. The typical features are well illustrated in the following three cases, in which the diagnosis was made during life; one of the patients survived for the remarkably long period of twenty-seven months.

CASE 1.—A clergyman, 45 years of age, first came under my observation on March 12, 1937, through the courtesy of Doctors A. M. Meads and Harold G. Trimble. At this time he was complaining of palpitation and shortness of breath of two weeks' duration. He had had, also, for some time, fatigue and a feeling of weight behind the sternum and in the left shoulder region, but no pain. Peridental infection had been known to be present for a period of about two years.

Received for publication Dec. 8, 1938.

He was found to have auricular fibrillation, which was promptly abolished by means of quinidine. A faint systolic murmur could be heard at the apex, but there was no other evidence of heart disease. Peridental infection was demonstrated, and it was thought that this might have produced toxic myocarditis, and that the symptoms were aggravated by the emotional stresses resulting from the patient's temperament and type of life. The diseased teeth were removed, and the patient returned to work.

During April, there continued to be some complaint of a heavy feeling in the precordial region. The systolic apical murmur became more definite, and there were occasional premature beats. On May 21, some muffling of the aortic second sound was noted. The blood pressure was 100/75. Fluoroscopic examination showed some dilatation of the first portion of the aorta. The blood Wassermann reaction was reported negative. At this time there was some complaint of precordial distress at long intervals.

On July 25, 1937, the patient collapsed in his pulpit and was brought to the hospital. He stated that for several days previously he had had, at times, considerable discomfort behind the upper sternum, extending to the left shoulder region. He had not ceased his activities and, on the contrary, had visited a lake resort where he undertook considerable physical exertion. Immediately before the collapse he had a sensation of a couple of sharp "thuds" in his chest, followed by weakness.

On examination he was found to be in mild shock, with cold, clammy perspiration and coldness of the extremities. The pulse was rapid and of the Corrigan type. Loud aortic systolic and diastolic murmurs were present. The percussion outline was not appreciably changed. There was flaccid paralysis of the leg muscles, both anterior and posterior groups, on both sides, with weakness of the hamstrings. There was an area of anesthesia on the right side, beginning on the lateral aspect of the right thigh in the midportion, extending downward, encircling the leg at about the midportion, and involving the entire foot. The paralysis on the left side cleared up within a few minutes, but that on the right persisted.

On the following day a similar area of hypesthesia appeared on the left side, and also marked weakness of the muscles of the left leg and of the hamstrings. There was hypesthesia in the saddle area, and marked difficulty in voiding. The muscles of the right leg and foot remained paralyzed. A spinal puncture was done, and the fluid found to be entirely normal except for increased pressure. The urine was normal. There were a slight secondary anemia, low-grade fever, and leucocytosis. Supportive measures were employed, and large doses of iodides and customary doses of bismuth were given. The paresis and hypesthesia on the left side disappeared within a few days. The heart murmurs varied in quality and intensity from time to time. Fever and moderate leucocytosis continued, but the anemia did not increase. Repeated blood cultures, a second spinal fluid examination, and several blood Wassermann tests were entirely negative. A Kline exclusion test was also negative. Roentgenologic studies at the bedside were inconclusive. Electrocardiograms showed only slurring of the R wave of Lead III, and no evidence of coronary occlusion.

At this time we were having much trouble with the patient from the psychic standpoint. He had previously been observed to be a hypertonic, if not hypomanic, type, very intense, highly reactive, and emotionally unstable. His physical incapacity exaggerated these personality traits to the point of actual mental derangement. There were times when he would be intensely cyanotic, with respiration of a shallow, grunting character, and, occasionally, of Cheyne-Stokes type. These manifestations occurred mostly during sleep. A little later there was a rather intense, but transient, hematuria, without evidence of infection. The circulation in the legs gradually became more and more feeble, until the development of marked pain, with discoloration on the slightest pressure, made us fear gangrene. This was especially marked on

the right side. Death, which occurred September 4, 1937, was due to exhaustion and terminal bronchopneumonia.

Post-mortem examination, by Dr. Paul Michael, disclosed a rent through the intima, completely encircling the aorta, about an inch above the free margins of the aortic valve cusps. The valve was normal. The dissection had extended proximally, forming a large aneurysm, covered only by adventitia and visceral pericardium, which projected backwards and to the right within the pericardial sac, compressing the right auricle. Dissection had occurred distally around the aortic arch and posteriorly and slightly to the right, throughout the entire length of the descending

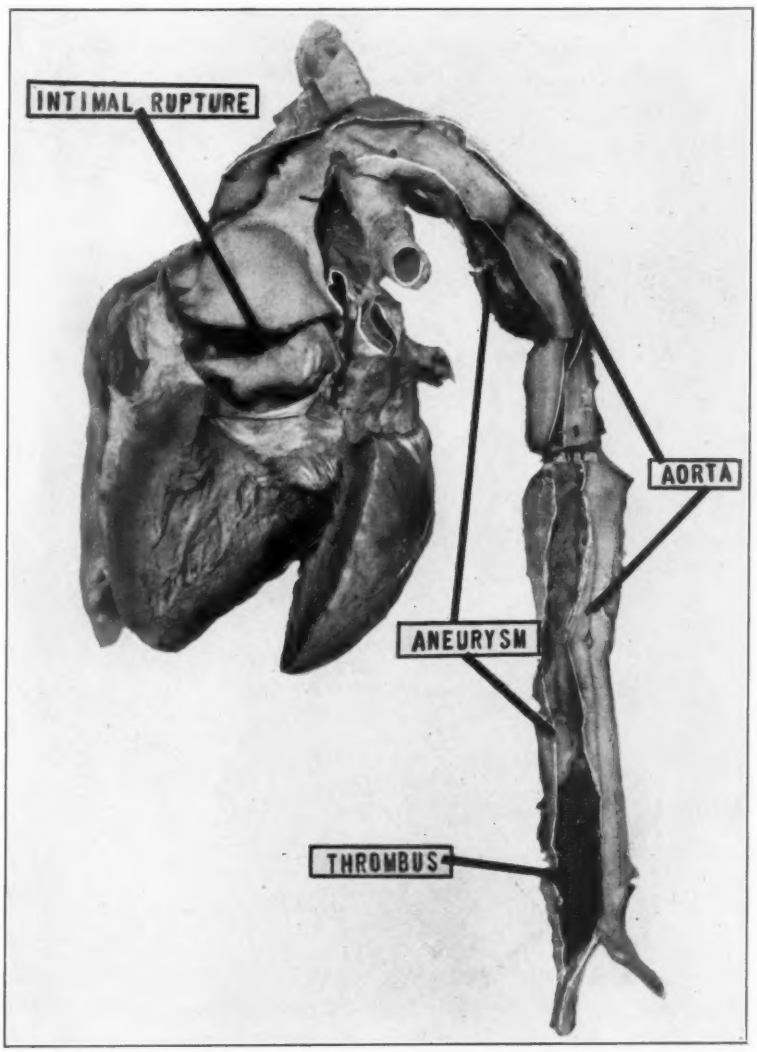


Fig. 1.—(Case 1) Anterior view, showing intimal rupture encircling the ascending aorta, with a dissecting aneurysm extending to the bifurcation. Note the large thrombus in the terminal portion of the aneurysm, mechanically obstructing the iliac orifices.

thoracic and abdominal portions of the aorta, stopping at the bifurcation. On the right side the intercostal arteries from the third to the eleventh, inclusive, were ruptured. The subcostal and lumbar arteries were ruptured bilaterally. The renal

arteries were considerably obstructed, especially the right. The terminal portion of the aneurysm was filled with thrombus and bulged into the lumen of the aorta at the bifurcation in such a way that the orifice of the right common iliac was almost completely obstructed and that of the left was markedly narrowed. The central nervous system was not examined.

Comment.—From the day of the July attack, dissecting aneurysm of the aorta seemed to me the most plausible diagnosis. As the symptoms progressed this impression became a positive conviction. The development of the heart lesions was too rapid for a syphilitic process, and the fact that the serologic reactions were persistently negative, even after iodide and bismuth treatment, was very much against such a diagnosis. To explain the neurologic changes as a result of subacute bacterial endocarditis would require the assumption that emboli had lodged in the lower lumbar and sacral segments of the cord, when

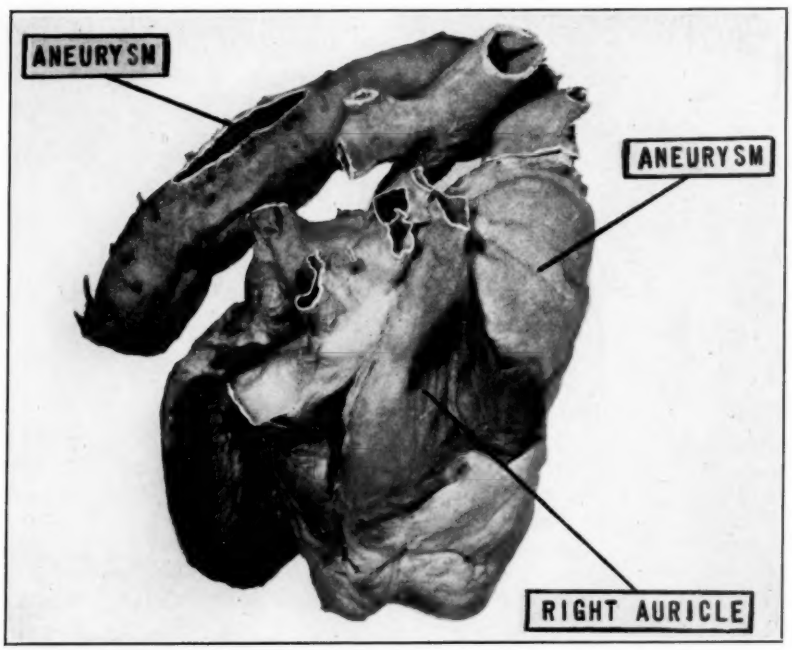


Fig. 2.—(Case 1) Posterior view. The parietal pericardium has been removed. Note the relation of the intrapericardial portion of the aneurysm to the right auricle.

there was no evidence of embolism elsewhere. This possibility seemed too remote for serious consideration. The persistently negative blood cultures and the failure of the anemia to progress were also against this diagnosis. On the other hand, the formation of a dissecting aneurysm could readily explain the sudden occurrence of collapse, with the rapid development of signs of aortic insufficiency from deformity of the aortic valve ring, and of neurologic signs from interference with the blood supply of the spinal cord. Extension of the aneurysm into one or

both renal arteries, or compression of these arteries by the aneurysm, could account for the hematuria. Compression of the iliac vessels could account for the circulatory impairment in the legs. Failure to demonstrate roentgenologic evidence of aneurysm did not militate against the diagnosis under the circumstances. Patients so acutely ill, in whom this diagnosis is being considered, often cannot be moved about with sufficient freedom to permit the utilization of all the refinements of radiographic technique required to visualize the structures involved.

This case illustrates the fact that the highly characteristic pain of dissecting aneurysm is not invariably present, even though the rent in the intima may be large and the aneurysm extensive. The case was also atypical in that there was no evidence of antecedent hypertension. The sudden collapse, with the coincident development of heart murmurs, fever, leucocytosis, anemia, neurologic manifestations, circulatory changes in the legs, and, finally, hematuria, led to the diagnosis. Although the occurrence of neurologic changes in the legs has been pointed out by others,[6] their diagnostic significance has perhaps not been sufficiently emphasized, and an explanation of the mechanism of their production may be of interest. The upper portion of the spinal cord receives its blood supply from the subclavian arteries through the anterior and posterior spinal branches of the vertebral arteries. As the anterior and posterior spinal arteries course downward on the pia mater of the spinal cord, they are supplemented by anastomotic branches from the spinal branches of the vertebral arteries, the deep cervical arteries, and the intercostal and lumbar arteries. The first two pairs of intercostal arteries arise from the superior intercostal branches of the subclavian arteries, but the remaining intercostal arteries and the lumbar arteries arise directly from the posterior aspect of the aorta. Since dissecting aneurysms usually pass down the posterior wall of the aorta, rupture of several pairs of the intercostal and lumbar arteries not infrequently occurs. In this way there may be sufficient interference with the blood supply to the lower cord to produce impairment of sensory and motor function of variable extent and intensity. Because of the free anastomotic blood supply of the spinal cord, these changes will frequently be transitory. The occurrence of hematuria, or even anuria, as a result of extension of the aneurysm into the renal artery, has been previously described[7] and is readily understandable. When the intima ruptures but a short distance above the aortic valve, dissection proximally is likely to deform the valve ring, giving rise to aortic insufficiency with its typical diastolic murmur and Corrigan pulse. Rupture of the aneurysm into the pericardial sac has frequently occurred at a point posteriorly and to the right, lateral to the right posterior cusp of the aortic valve. It was at this point that the large intrapericardial aneurysm formed in this case. It is likely that much of the dyspnea and cyanosis in this case was due to compression of the right auricle by this aneurysm.

The post-mortem examination unfortunately gave no clue to the nature of the lesions of the aorta which preceded the sudden collapse. That some such lesions existed is suggested by the complaint of precordial distress which preceded the attack by several months, and by the fluoroscopic finding of enlargement and increased density of the ascending portion of the aorta two months prior to the attack. The observations of Krukenberg[8] and Tyson[9] that the initial lesion in many of these cases is rupture of a vas vasorum and splitting of the walls of the aorta by the formation of a hematoma afford a possible explanation. The probability of the existence of such a mechanism is, however, purely a matter for speculation in the present instance.

CASE 2.—A retired postman, aged 68 years, was seen in consultation with Dr. A. Lyle Winslow, on Nov. 19, 1937. This man was known to have had hypertension for several years, and albumin and casts had been found in the urine. He had been as well as usual, however, until about two weeks previously, when, in the morning, after visiting the bathroom and starting to ascend the stairs, he was stricken with a severe agonizing pain which he said felt like knives turning and twisting about within his chest. The pain extended through to the back and into the epigastric region. It did not radiate to the arms. There was no dyspnea, although his breathing was somewhat restricted because of pain. He showed signs of shock, and large doses of morphine were required for relief of the pain. His blood pressure fell below 100, systolic, and there was some irregularity of the heart's action. Within the first day the pain subsided, but returned at intervals, though never so acutely. The blood pressure rose about to its previous level within a few days. Fever ranging to about 102° F. had been constantly present. An electrocardiogram, made three days following the attack, showed only left axis deviation, with none of the findings characteristic of coronary occlusion.

Examination revealed a large man, well-preserved for his stated age, sitting up in bed and moving about actively. He was of the hypertonic personality type, obviously willful and difficult to control. His lips and mucous membranes appeared a little cyanotic, but he was not dyspneic. The pulse rate was 104 and the pulse was regular, the blood pressure measured 160/100 in both arms, and the temperature was 101.6° F. The vessels of the extremities showed moderate sclerosis, but no beading. The pulsations were equal on both sides, somewhat diminished in the lower extremities but not out of proportion to the arteriosclerosis present. The head, neck, lungs, and abdomen were apparently normal. There was no peripheral edema. The heart did not seem appreciably enlarged to percussion, and the sounds were clear and distinct and of approximately normal quality. There was a faint, blowing, systolic murmur in the midprecordium, but no murmur could be heard along the spine. In the third week of the illness a second electrocardiogram was made which was not significantly different from the first. Fever and occasional mild retrosternal pain persisted until about six weeks after the onset, when death occurred suddenly.

Post-mortem examination showed a rent in the intima almost completely encircling the aorta in the descending portion of the arch. Dissection had occurred proximally about three centimeters and distally about eighteen centimeters. The terminal portion of the aneurysm was filled with organizing thrombus. The central portion had not thrombosed, and there was a large external rent through the adventitia and pleura into the left pleural cavity, which was filled with blood.

Comment.—Although the occurrence of pain of this character in a person of the kind described is highly suggestive of coronary occlusion with

myocardial infarction, there were certain aspects of this case which did not fit well with such a diagnosis. The severity of the initial symptoms and, especially, the height and duration of the fever would indicate a large area of infarction. If such were present an electrocardiogram made three days following the occurrence of the attack should certainly show characteristic changes. We should also expect distinct changes in the heart sounds, possibly a pericardial friction, persistent lowering of the blood pressure, and a greater degree of prostration than was exhibited by this patient. A diagnosis of dissecting aneurysm of the aorta seemed to fit the observed facts more closely. This case illustrates what would appear to be the minimum findings upon which the existence of a dissecting aneurysm could be surmised. The absence of electrocardiographic signs of coronary occlusion was an important diagnostic feature.

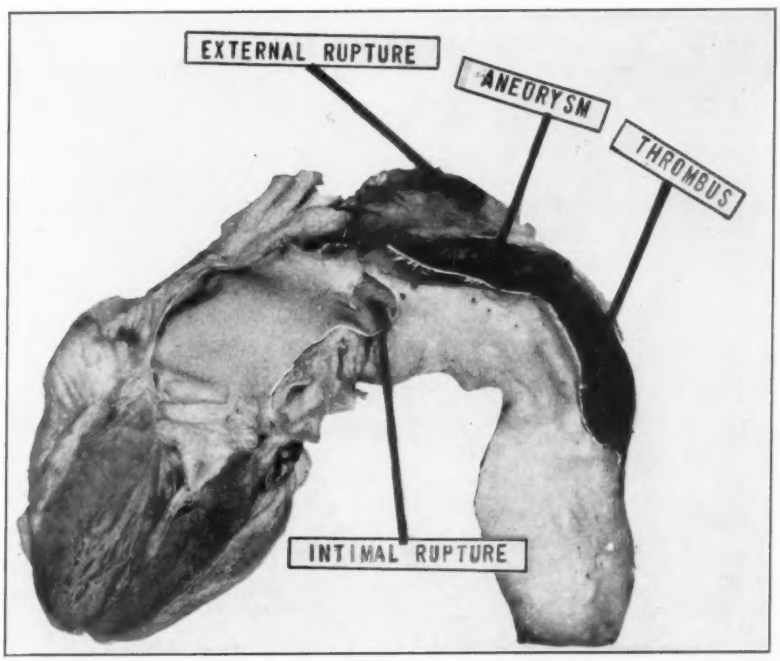


Fig. 3.—(Case 2) Intimal rupture at the isthmus, external rupture into the left pleural cavity.

CASE 3.—J. H. F., a man 43 years of age, was admitted to the Peralta Hospital on May 13, 1936, under the care of Dr. Charles F. Greenwood. I saw him in consultation on May 17. He had felt perfectly well previously, except that for about one week he had had to urinate once at night, and for about one month had had slight occipital headaches which were attributed to a refractive error. At 12:30 a.m., on May 13, he had, during sexual excitement, a sudden onset of gripping or constricting pain beneath the upper sternum which quickly passed downward through the chest and abdomen and, within a few minutes, to the back, apparently centering in the muscles along the spine, between the scapulae, and extending downward

into the lumbar region. In a half hour or so, a marked numbness of the left leg was noted, and with this an inability to move the left foot. The pain lessened for a short time, but within an hour became again very severe, so that one-half grain of morphine was required for relief. There was no headache or vomiting. The following morning, on his admittance to the hospital, the pain had abated somewhat. Vomiting had occurred twice, probably because of the morphine. Abdominal distention and rigidity, without tenderness, had developed. The left leg was perhaps not quite as warm as the right. The blood pressure was found to be 230/130. There was nothing else of note in the examination. During the next few days the distention was relieved with enemata. The numbness gradually disappeared from the left leg, passing off as a stocking is pulled off, but returned, for a while, the following day, in the left foot and lower third of the leg. Later, a "scalded" sensation was noted over the toes of the left foot, and also fairly severe cramplike pains in the anterior aspect of the left leg, with soreness in this region. On the morning of May 17 there was a localized area of acute tenderness in the midportion of the anterior surface of the left leg.

There had been no headache, vomiting, or diarrhea. The blood pressure had remained elevated despite the liberal use of nitrites. There had been a low-grade fever, not exceeding 100° F., and a leucocytosis of about 12,000, with 80 per cent polymorphonuclear cells. The urine was normal. The blood Wassermann and Kahn reactions were negative. There was radiographic evidence of a diffuse increase in the caliber and density of the aorta.

His personal medical history included evidence of a susceptibility to respiratory infections in childhood, and of questionable chorea at the age of 9 years. There had been some indefinite gastric disturbance between the ages of 25 and 27, while he was in China. Pyorrhea had been present and adequately treated one and a half years previously. A detailed family history was not available, but there was apparently a familial tendency to hypertension.

Examination at the time of the consultation, four days following the onset, revealed a well-developed and muscular man, apparently of his stated age, alert, cooperative, and not dyspneic or cyanotic or in obvious distress. The pupils reacted normally, the left being slightly irregular. The retinal arteries were somewhat constricted and definitely tortuous, particularly the secondary branches, but no hemorrhages or cotton-wool exudates were seen. The head and neck were otherwise normal. No abnormalities were found in the lungs or in the abdomen. The cardiac dullness was within normal limits. The action was forceful and regular, and the rate was a little rapid; a blowing systolic murmur of moderate intensity was heard at the apex. The blood pressure in the right arm was 196/124, and in the left, 220/140. The knee jerks were normal and equal, and no pathologic reflexes were obtained. The popliteal, dorsalis pedis and posterior tibial pulsations were not as strong in the left leg as in the right. He was unable to dorsiflex the left foot, to abduct it, or to extend the toes of this foot. The calf muscles and the extensors of the thigh were weak. The vibratory sense was normal. There was an area of anesthesia to touch, pain, and temperature covering the dorsum of the left great toe and the mesial half of the dorsum of the adjoining toe, extending upward upon the dorsum of the foot and converging to a point at about the level of the metatarsotarsal articulation. On the anterior surface of the middle portion of the left leg there was an area measuring about five centimeters transversely, by eight centimeters axially, which was red, slightly elevated, and tender to touch and pressure. The actual area of hyperesthesia corresponded roughly in size, shape, and position to the reddened area, but was slightly smaller and a trifle lower. Concentric with this there was a larger area, measuring about 8 × 10 centimeters, which was anesthetic to temperature. The fever lasted but a few days. The neurologic signs subsided gradually over a period of about two weeks. A few days subsequently bleeding

from the left kidney appeared without obvious cause, although infection later developed, possibly as a result of instrumentation. After the subsidence of the hematuria and pyelitis the patient returned to work and remained in fair health except for his hypertension, which slowly progressed. A roentgenogram of his chest, made two years following the acute attack, showed a diffuse widening of the aortic shadow which was more marked than it had been previously. It did not, however, show a double outline and could not be distinguished from a dilatation resulting from hypertension and arteriosclerosis.

In July, 1938, he began having some hematuria, and on a few occasions expectorated a little blood. On Aug. 12, 1938, he developed a severe headache and soon became unconscious. The spinal fluid was grossly bloody, and the clinical signs were those of subarachnoid hemorrhage. He died the following morning.

Fig. 4.—(Case 3) Roentgenographic and kymographic studies two years following onset show a broad aortic shadow indistinguishable from that caused by arteriosclerotic change.

Post-mortem examination, by Dr. Paul Michael, showed an old, healed, dissecting aneurysm which began at the level of the orifice of the left subclavian artery. Below this point the aorta was double until just above the bifurcation, where the true aortic channel became obliterated. The aneurysmal channel was larger than the true channel and surrounded the latter on the left and posteriorly, becoming more anterior in the abdominal portion. The lining of the aneurysm showed coarse longitudinal striation and numerous atheromatous plaques, especially in the abdominal portion. Microscopic examination revealed no endothelial lining. As the aneurysm passed downward, it had ruptured all of the intercostal and lumbar arteries on the left and had penetrated the left renal, the superior mesenteric, and the right iliac arteries. The true aortic channel supplied the right intercostal and lumbar arteries and the right renal artery. There was a small communication between the two

channels just anterior to the orifice of the left renal artery. Just above the bifurcation the true aortic channel became obliterated, and the aneurysm constituted the entire vessel. Rupture had, however, occurred into the left common iliac artery at its point of origin. The right common iliac was involved by the dissection as far as it was traced.

Associated pathologic findings were hypertrophy of the left ventricle, pleuritis on the left side, and bilateral nephrosclerosis. The central nervous system was not examined.

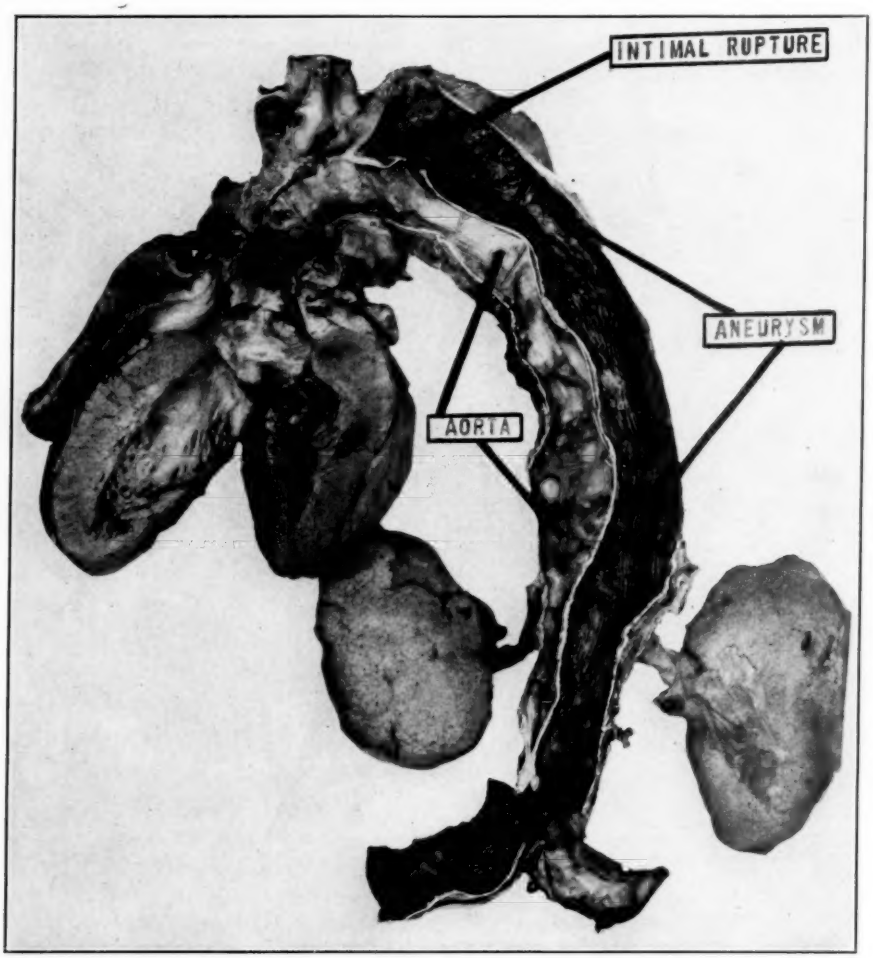


Fig. 5.—(Case 3) Intimal rupture at the isthmus, with double aortic channel. Obliteration of aorta just above the bifurcation by approximation of its walls. Single left iliac channel not involved by aneurysm. Large aneurysmal channel, and small, apparently functionless, true channel in right iliac artery.

Comment.—At the onset it was obvious that the patient had essential hypertension and that a circulatory accident had occurred, the exact nature of which was far less obvious. The presence of a dissecting aneurysm was strongly suspected, but it was thought that the pain and neurologic signs might also be the result of myelomalacia. After the ap-

pearance of the hematuria it seemed that only a dissecting aneurysm could produce all of the phenomena observed in this case. There were no manifestations which were inconsistent with such a diagnosis. Most dissecting aneurysms occur in males between forty and sixty years of age. There is usually a preceding hypertension. The onset is typically sudden, with pain and collapse, followed, if death does not ensue immediately, by fever and leucocytosis. The "wandering"[10] pain felt by this patient, first anteriorly in the chest, then in the epigastrium, and later in the dorsal and lumbar regions, is characteristic of dissecting aneurysm involving the aortic arch and the descending aorta, although, as previously mentioned, it is not invariably present. The neurologic manifestations in the legs, which developed so quickly in this case, are of great diagnostic importance in association with evidence of a vascular accident within the chest. No such manifestations would be expected in connection with coronary occlusion, nor could the intense chest pain and collapse reasonably be ascribed to a primary spinal cord lesion. The absence of electrocardiographic evidence of myocardial infarction and the fact that the spinal fluid was normal were entirely consistent with the diagnosis of dissecting aneurysm. The circulatory changes in the legs developed gradually and were not intense. The converse is usually true of obstruction from a riding embolus. The occurrence of hematuria, easily explainable as the result of extension of a dissecting aneurysm into the renal artery, was exceedingly difficult to relate to the previously observed symptoms and signs by any other hypothesis. There was also significance in the fact that the blood came from the left kidney, that the neurologic signs were found on the left side, and that the circulatory changes were more marked in the left leg. This would be expected, in accordance with the anatomic relations described above, if the dissecting aneurysm passed down the descending thoracic and abdominal aorta posteriorly and a little to the left, involving the left renal artery. The feature of this case which was least consistent with a diagnosis of dissecting aneurysm was the recovery of the patient. Recovery may, however, sometimes occur, as a result either of thrombosis within the cavity of the aneurysm and organization of the thrombus, or of a second rupture through the intima of the aorta at the distal termination of the aneurysm. In the latter type, which is statistically more frequent, a double aortic channel is formed. The aneurysmal channel may become endothelialized. This type of healing could be surmised to have occurred in this case. The fairly rapid subsidence of the circulatory changes in the legs, and the absence of roentgenologic evidence of a double outline within the aortic shadow were more suggestive of re-entry of the aneurysm into the aorta than of healing by thrombosis. The extension of the aneurysm into the celiac axis and the superior mesenteric artery, which was found at the post-mortem examination, was not predicted.

SUMMARY

Reference to published accounts of thirty authentic cases of dissecting aneurysm of the aorta shows a rapid increase in the frequency with which the condition is being recognized. Three additional cases, in which the diagnosis was correctly made, illustrating the clinical features of the condition, are reported. One of these patients lived twenty-seven months after the acute attack. In this case it was possible to forecast the post-mortem finding of extension of the aneurysm into the left renal artery, and the presence of a double aortic channel. Since roentgenologic studies can only occasionally be of help in establishing the diagnosis, and the electrocardiogram is of value chiefly when it shows no signs of myocardial infarction, the chief reliance in diagnosis must be placed on clinical features. Patchy and bizarre neurologic changes in the legs, occurring as a result of circulatory deficiencies in the spinal cord from rupture of intercostal and lumbar arteries by a dissecting aneurysm, are of great diagnostic importance. Hematuria or anuria, in association with evidences of a circulatory accident within the chest, are also important as indicative of involvement of one or both renal arteries by an aneurysm. Attention to the clinical features should enable the diagnosis to be made with still greater frequency.

REFERENCES

1. Nicholls, Frank: Some Observations on Aneurysms in General. Philosophical Transactions of the Royal Society, London **35:** 440, 1728-29.
2. Swaine, Keyworth, and Latham, P. M.: A Case of Dissecting Aneurysm of the Aorta, Trans. Path. Soc. London **7:** 106, 1856.
3. Shennan, T.: Medical Research Council Special Report Series No. 193. London. His Majesty's Stationery Office. 1934.
4. (a) Hirschbeck, F. J., and Boman, P. G.: A Case Report of Dissecting Aneurysm of the Aorta With Distinctive X-ray Findings, Minnesota Med. **5:** 724, 1922 (one case).
   (b) Samson, Paul C.: Dissecting Aneurysm of the Aorta, Including the Traumatic Type: Three Case Reports, Ann. Int. Med. **5:** 117, 1931 (One case, diagnosis made by Dr. Roger T. Vaughan).
   (c) Kellog, F., and Heald, A. H.: Dissecting Aneurysm of the Aorta. Report of a Case Diagnosed During Life, J. A. M. A. **100:** 1157, 1933 (one case).
   (d) Lounsbury, J. B.: Clinical Symptoms and Signs of Dissecting Aneurysm With Report of a Case Diagnosed During Life, Yale J. Biol. and Med. **7:** 209, 1935 (one case).
   (e) Weiss, Soma: Clinical Course of Spontaneous Dissecting Aneurysm of the Aorta, M. Clin. North America **18:** 1117, 1935 (one case).
   (f) Gurin, D., Blumer, J. W., and Derby, R.: Dissecting Aneurysm; Diagnosis and Operative Relief of Acute Arterial (Iliac and Femoral) Obstruction Due to This Cause, New York State J. Med. **35:** 1200, 1935 (one case).
   (g) Löffler, W.: Zur Klinik und Diagnostik der Aortenruptur, Schweiz. med. Wchnschr. **16:** 790, 1935 (three cases).
   (h) Osgood, E. F., Gourley, M. F., and Baker, Russel L.: Diagnosis of Dissecting Aneurysm of the Aorta, Ann. Int. Med. **9:** 1398, 1936 (two cases).
   (i) Glendy, Robt. E., Castleman, Benjamin, and White, Paul D.: Dissecting Aneurysm of the Aorta: A Clinical and Anatomical Analysis of Nineteen Cases (Thirteen Acute) with Notes on the Differential Diagnosis, AM. HEART J. **13:** 129, 1937 (two cases).
   (j) Roesler, H., Gifford, U. G., and Betts, W.: Dissecting Aneurysm of the Aorta Correctly Diagnosed, with Description of a Sign Heretofore not Mentioned, AM. HEART J. **13:** 426, 1937 (one case).

(k) McGeachy, T. E., and Paullin, J. E.: Dissecting Aneurysm of the Aorta, J. A. M. A. **108:** 1690, 1937 (three cases).
(l) Blackford, L. Minor, and Smith, Carter: Coronary Thrombosis vs. Dissecting Aneurysm in Differential Diagnosis, J. A. M. A. **109:** 262, 1937 (one case).
(m) Middleton, Wm. S., and Porter, Reno R.: Diagnosis of Spontaneous Dissecting Aneurysm of the Aorta, Trans. Ass'n. Am. Physicians **52:** 67, 1937 (one case).
(n) Boyd, Linn L., and Werblow, Chas. S.: Coarctation of the Aorta, Dissecting Aneurysm and Aneurysmal Dilatation of the Left Vertebral Artery: Report of a Case, Ann. Int. Med. **11:** 845, 1937 (one case).
(o) Leik, D. W.: Diagnosis of Dissecting Aneurysm with Report of a Case, J. Iowa State Med. Soc. **28:** 13, 1938 (one case).
(p) Claiborne, T. S., and Holler, Emory D.: Dissecting Aneurysm of the Aorta and Course for Fifty-three Days, AM. HEART J. **15:** 358, 1938 (one case).
(q) Hamberger, Morton, Jr., and Ferris, Eugene B., Jr.: Dissecting Aneurysm: A Study of Six Recent Cases, AM. HEART J. **16:** 1, 1938 (two cases).
5. Keinbock, Robert, and Weiss, Konrad: Ein Fall von Aneurysma dissecans der Brustaorta, Fortschr. a. d. Geb. d. Röntgenstrahlen **44:** 211, 1931.
6. (a) Kalischer: Aneurysma dissecans der Aorta mit Paraplegie, Berliner klin. Wchnschr. **51-2:** 1286, 1914.
(b) Pannhorst, R.: Symptomatologie und Diagnose der Aortenruptur und des Aneurysma dissecans, Deutsches Arch. klin. f. Med. **175:** 115, 1933.
7. (a) Perry, Thomas M.: Dissecting Aneurysms of the Aorta With a Report of Five Cases, AM. HEART J. **12:** 650, 1936.
(b) Glendy, Castleman, and White, loc. cit.
8. Krukenberg, Ernst: Beiträge zur Frage des Aneurysma dissecans, Beitr. z. path. Anat. u. z. allg. Path. **67:** 329, 1920.
9. Tyson, M. Dawson: Dissecting Aneurysms, Am. J. Path. **7:** 581, 1931
10. Löffler, loc. cit.

CONGENITAL HEART DISEASE IN CHILDHOOD, WITH SPECIAL REFERENCE TO PROGNOSIS

RACHEL ASH, M.D., AND EDWARD HARSHAW, JR., M.D.
PHILADELPHIA, PA.

WITHIN recent years the subject of congenital cardiac defects has aroused increasing interest, inspired in great part by the efforts of Dr. Maude E. Abbott to clarify the differential diagnosis through the analysis of case reports and of pertinent clinical and laboratory studies. Under the stimulus of her interest, moreover, information concerning the incidence at autopsy of such congenital defects has been assembled from various hospitals in the United States and Canada (Table I).[1]

The present paper is based on an analysis of the records of all children with congenital cardiac defects admitted to the wards or cardiac clinic of the Children's Hospital during the years 1922 to 1936, inclusive. Since we were interested not only in the incidence of congenital cardiac lesions but also in their prognostic significance, the effort was made during the first six months of 1938 to trace and bring back for examination all children not under current observation.

During these fifteen years 230 children with a presumptive diagnosis of congenital defect were seen at the Children's Hospital. In infancy the diagnosis was based on the existence of an intense murmur not associated with marked anemia. In older children a congenital lesion was suspected when a murmur was heard best at sites not characteristic of the acquired valvular lesions (Table II). In 36 cases (15.6 per cent) a thrill was palpated. At all ages the diagnosis was frequently aided by the roentgenologic finding of cardiac enlargement or change in contour, or by abnormalities noted in the electrocardiogram. Persistent cyanosis was present in 67 of the 217 children who were 2 years of age, or older; clubbing of the fingers was seen in 16 cases.

In one-half of the cases, the patients were first seen when they were infants (Table III). The existence of a cardiac defect was noted elsewhere during the first months of life in thirty children who later came under observation at the Children's Hospital. The diagnosis of a congenital lesion was therefore made early in infancy in 64 per cent.

In the total group of 230, 117 were boys (50.9 per cent) and 113 girls (49.1 per cent). Fifty-one were negroes (22.2 per cent) and

From the Department of Pediatrics, University of Pennsylvania Medical School, and the Children's Hospital.
Read before the Philadelphia Pediatric Society, Jan. 10, 1939.
Received for publication Dec. 14, 1938.

TABLE I

COMPARATIVE INCIDENCE OF CONGENITAL CARDIAC DEFECTS FOUND AT NECROPSY

	TOTAL NUMBER AUTOPSIES	CONGENITAL HEART DISEASE		AUTOPSIES NEONATAL PERIOD		AUTOPSIES 1-2 YEARS		AUTOPSIES 2 YR.—ADULT		CHILDREN OVER 2 YEARS AUTOPSIES	
		NO.	PER CENT	NO.	PER CENT CONGENITAL HEART DISEASE	NO.	PER CENT CONGENITAL HEART DISEASE	NO.	PER CENT CONGENITAL HEART DISEASE	NO.	PER CENT CONGENITAL HEART DISEASE
Leech—Baltimore Johns Hopkins Hospital	13,115	170	1.29								
Terplan and Sanes Buffalo General Hospital	336	21	6.3								
Philpott Montreal Hospitals	7240	80	1.1	759	4.7	957	2.8	5522	0.3		
Nicholson—Washington, D. C. Pediatric Service—four hospitals	1851	37	2.0								
McGinn—Boston Massachusetts General Hospital	7500	67	0.9	70	10.0	146	4.6			2159	0.8
Ramek and Propst—Philadelphia University of Pennsylvania Hospital	4255	36	0.85	398	1.75	223	4.95	3034	0.52		
Szypulski—Philadelphia Philadelphia General Hospital	7500	111	1.4	157	4.4	184	13.04	7159	1.1		
Gibson and Clifton—Chicago Children's Memorial Hospital	1950	105	5.4								
Present series—Philadelphia Children's Hospital	1075	34	3.16	116	3.45	710	3.94			236	0.89

TABLE II

SITES AT WHICH MURMURS WERE BEST HEARD IN 230 CASES OF CONGENITAL CARDIAC ANOMALY

LOCATION OF MURMUR	NUMBER OF CASES
First and second left interspaces	55
Third left interspace	27
Below left clavicle and at fourth left interspace	50
Fourth interspace, left of sternum	48
First to third right interspaces	3
Diffuse precordial, no localization	32
No murmur	15

TABLE III

AGE WHEN FIRST SEEN IN 230 CASES OF CONGENITAL CARDIAC ANOMALY

AGE IN YEARS	NUMBER OF CASES
Under 1	117
1	30
2-4	35
5-9	30
10-12	18

179 white (77.8 per cent). Information concerning 189 (80.2 per cent) was obtained in 1938 (Table IV). Of the 41 children who could not be located, 28 had attained the age of at least 2 years when they were last seen, so that the course in the first two years is known in 217 instances, or 94.3 per cent of the group (Tables V and VI).

TABLE IV

PROGNOSIS IN 230 CASES OF CONGENITAL CARDIAC DEFECT

FIRST ADMISSION	TOTAL NO. PATIENTS	PATIENTS TRACED		DEATHS		LIVING PATIENTS, AGED 2 OR MORE; FUNCTIONAL CLASSIFICATION*		
		NO.	PER CENT	NO.	PER CENT	I	IIa	IIb
Wards	131	112	85.5	86	66.5	23	6	6
Clinic	99	77	77.7	16	20.8	66	9	4
Total group	230	189	82.2	102	53.9	89	15	10

*The functional classification is based on the "Criteria" of the American Heart Association. I indicates physical activity not limited; IIa, activity slightly limited; IIb, activity greatly limited. All individuals in Class IIb and 5 in Class IIa were cyanotic. Two individuals in Class IIa and 6 in Class I had suffered transient attacks of cyanosis in infancy.

TABLE V

AGE OF LIVING PATIENTS WHEN LAST SEEN

AGE IN YEARS	BORN SINCE 1922		BORN BEFORE 1922		TOTAL	
	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT
2-4	20	23.8	5	16.1	25	21.7
5-9	26	30.9	4	12.9	30	26.1
10-14	26	30.9	5	16.1	31	26.9
15-26	12	14.4	17	54.9	29	25.3
Total	84	100.0	31	100.0	115	100.0

TABLE VI

AGE AT DEATH

AGE IN YEARS	CYANOTIC*		NONCYANOTIC		TOTAL	
	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT
Under 6/12	35	50.0	8	25.0	43	42.1
6/12-1	20	28.6	12	37.5	32	31.4
2-4	5	7.1	8	25.0	13	12.7
5-9	6	8.6	2	6.25	8	7.8
10-19	4	5.7	2	6.25	6	6.0
Total	70	100.0	32	100.0	102	100.0

*Includes all types of cyanosis: 47, persistent; 3, recurrent; 16 terminal.

DEATHS

The total number of deaths was 102 (53.9 per cent of those traced in 1938, and 47 per cent of those who were 2 years of age, or older, when they were last examined). Half of the deaths occurred among boys and half among girls. In 20 per cent of the cases the children were negroes.

Eighty-four per cent of all deaths occurred among the children who had been seen first in the wards. The majority of these, when first seen, had presented symptoms of serious illness. Eighteen patients were moribund on admission. Sixteen per cent of the deaths occurred among the patients who came originally to the cardiac clinic. In many of these the lesion had been discovered accidentally during routine examination. Eighty per cent of the children first seen in the clinic had never required hospitalization, if admissions for tonsillectomy were excluded.

The death rate on the wards had been 70.6 per cent for infants below the age of one year. Of the 72 children who had been admitted as babies, 91.6 per cent were dead in 1938. Of the 42 infants who had originally come under observation in the cardiac clinic, one-third had died. Among the 94 children who had reached school age, the incidence of deaths was 11 per cent.

Seventy-three per cent of the deaths had occurred within the first year of life, and 78 per cent within the first two years (Table VI). In Baltimore,[1a] 75 per cent of the deaths in children with congenital cardiac anomalies took place within the first year. Half of the deaths in Irvine-Jones' series[2] occurred below the age of six months.

Deaths Among Individuals Born Since 1922.—Since the majority of deaths had occurred in the first 2 years of life, the inclusion of individuals born prior to 1922, who had come under observation after safely weathering the period of infancy, would tend to lower the death rate artificially. We have, therefore, made a separate analysis of those born during the years 1922-1936, comprising 191 children, 93.7 per cent of whom had been followed at least until their second birthday (Table VII). There were 95 deaths (53 per cent).

TABLE VII

PROGNOSIS ACCORDING TO AGE (INDIVIDUALS BORN SINCE 1922)

AGE YR.	NO. OF CASES	NUMBER TRACED	DEATHS		DEATHS	
			NO.	PER CENT	CYANOTIC GROUP* PER CENT	NONCYANOTIC PER CENT
1	191	183	59	37.7	50.0	24.8
2	191	178	79	44.4	63.4	32.6
5	151	138	68	49.4	78.5	36.4
10	102	81	37	45.7	73.7	37.1

*In the cyanotic group were placed only individuals with continuous cyanosis or persistent recurrent attacks. Individuals with transient cyanosis early in life, or those who presented terminal cyanosis were considered noncyanotic.

Cause of Death.—In slightly over one-half of the cases (52.9 per cent) the final illness was of infectious origin. Pneumonia headed the list of infections, causing 39 per cent of the deaths. Bacterial endocarditis was the terminal event in only two cases. Three deaths were due to each of the following: acute meningitis, septicemia, tuberculosis, and acute gastroenteritis. In one-third of the deaths circulatory inadequacy was a prominent feature. There were two instances of sudden death without preceding symptoms. The first occurred in an infant with heart block; the second, in a nine-year-old girl with aortic stenosis (diagnosis proved by necropsy) who fell dead following a blow over the precordial region received in a childish quarrel.

Of the 38 patients who came to necropsy, there were 10 children in whom no cause of death could be found other than circulatory failure. All were cyanotic. Of 17 patients belonging to the acyanotic, or late cyanotic, groups, according to Dr. Abbott's classification,[3] 15, or 88.2 per cent, died of infection, and 1, or 6 per cent, of circulatory failure. A previously mentioned child with aortic stenosis died suddenly. Of 21 patients belonging to the cyanotic group, 57 per cent died of infection and 43 per cent as a result of the cardiac defect itself.

INFLUENCE OF CYANOSIS ON PROGNOSIS

Fifty-six per cent of the children—80 per cent of the living individuals and 30 per cent of those that had died (Table VIII)—had never been cyanotic. The death rate of the cyanotic infants during the first year of life was twice that of the noncyanotic, and rose progressively with age as the children gradually succumbed to infection or circulatory failure (Fig. 1). After the second year of life there was a marked drop in deaths among the noncyanotic individuals. Among 94 children who had attained the age of six years, or over, 13 were cyanotic. Eighty per cent of these cyanotic school children were dead at the end of the period of observation, whereas only 5 per cent of the noncyanotic school children had died.

The prospect for the cyanotic victims of congenital cardiac defects is not very hopeful. In the present series, of 16 individuals with

persistent cyanosis who reached the age of 5 years, 10 were leading lives of greatly restricted activity. Of the 7 who reached the age of 10 years, 4 were cardiac cripples. Four children lived past their fifteenth birthday. One has since died; two have always been incapable of much exertion.

TABLE VIII

INCIDENCE OF CYANOSIS IN 217 INDIVIDUALS TWO YEARS OF AGE, OR OLDER

	BORN SINCE 1922				BORN BEFORE 1922				TOTAL	
	LIVING		DEAD		LIVING		DEAD			
	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT	NO.	PER CENT
No cyanosis	66	78.5	29	30.5	25	80.8	1	14.3	121	55.8
Persistent	10	11.9	47	49.5	6	19.2	4	57.1	67	30.9
Recurrent in early life	8	9.6	3	3.2	0	0.0	1	14.3	12	5.5
Terminal	0	0.0	16	16.8	0	0.0	1	14.3	17	7.8
Total	84	100.0	95	100.0	31	100.0	7	100.0	217	100.0

In an occasional instance, however, the outlook is by no means hopeless. There was the talented musician with the tetralogy of Fallot who died in his sixtieth year;[4] the woman, 62 years of age, working as a librarian, without complaints other than of cyanosis;[5] and the cyanotic laborer who lived to his forty-first year, dying not of any cardiac disturbance, but of uremia due to chronic glomerulonephritis.[6]

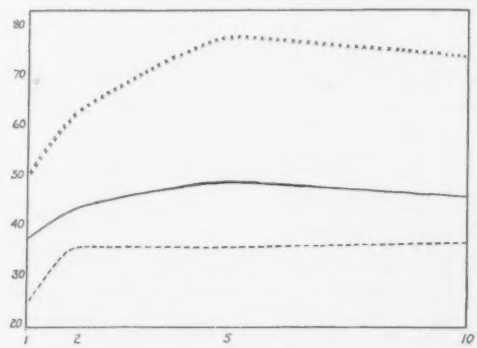


Fig. 1.—Percentage of deaths among children with congenital cardiac anomalies born during the years 1922 to 1936. The dash line indicates the noncyanotic individuals; the crosses, the cyanotic individuals; the solid line, the total group. Only individuals with continuous cyanosis or persistent recurrent attacks were placed in the cyanotic group. Individuals with transient cyanosis in early life or those who presented cyanosis as a terminal phenomenon were placed in the noncyanotic group. The numbers at the bottom represent age in years, those at the side, percentage of deaths.

Cyanotic women have given birth to normal children.[7] Snelling[8] mentions the case of a man, 54 years of age, cyanotic from birth, as were his mother and grandmother, himself the father of three children, two of whom were cyanotic because of congenital heart disease.

The oldest cyanotic individual in the present series is a boy, 21 years of age, intelligent and with many interests, attending a technical school to which he had been granted a scholarship. Six years ago, this boy's erythrocyte count was 9,000,000, and his hemoglobin 150 per cent, which would seem to controvert the statement of Vaquez and Quiserne, quoted by Abbott,[9] that a count above 6,000,000 is always of grave prognostic import. In our group of living cyanotic children the average of 20 erythrocyte counts was 7,390,000, the average hemoglobin was 118 per cent, the maximum erythrocyte count 11,180,000, and the maximum hemoglobin 165 per cent. Of the cyanotic individuals that died, the average of 25 erythrocyte counts was 5,380,000, the average hemoglobin was 90 per cent, the maximum erythrocyte count 7,820,000, and the maximum hemoglobin 128 per cent.

Cyanosis preceded the appearance of clubbing by varying intervals of time. Clubbing of the fingers occurred in 16 individuals, the youngest being 4 months of age. In two cyanotic children, aged 10 and 16 years, respectively, the fingers were not clubbed.

OTHER ASSOCIATED ANOMALIES

Mental Deficiency.—Eighteen children (7.8 per cent) were Mongolian idiots. Three children were microcephalic. Two others were inmates of institutions for the feeble-minded. Eight children, enrolled in the public schools, had been placed in "orthogenic backward" classes maintained for pupils with intelligence too low to enable them to keep up with the regular curriculum. In addition, three children below school age were mentally retarded. There were, thus, 34 children (14.5 per cent) with retarded mental development. The question may be raised whether such mental deficiency is due to a primary cerebral defect or is secondary to inadequate cerebral circulation. There is little doubt of the congenital origin of the cerebral abnormalities in Mongolian idiocy and in microcephaly. The most plausible assumption would be that in the remaining 13 children some form of cerebral aplasia was present.

Eighteen individuals presented associated defects other than cerebral maldevelopment. One of these, in addition, was microcephalic, and three were Mongolian idiots. In all, including the Mongolian idiots and microcephalics, there were 35 cases of associated congenital defect (10.9 per cent).

CLINICAL ASPECTS

Infants with congenital cardiac defects tend to be slow to gain weight and delayed in growth. Malnutrition of a degree sufficient to be noted in the clinical records was present in 69 children (30 per cent) of the present group. The marasmus of many of the infants admitted to the wards undoubtedly helped bring about the high mortality rate. In later life these children may remain dwarfed and of

fragile build. In some individuals, however, a spurt of growth occurs as puberty is reached.

Mental deficiency is a not infrequent occurrence, particularly among the noncyanotic individuals.

In infancy and early childhood, increased susceptibility to infections, especially respiratory, is common. Pneumonia, although a frequent cause of death, is not invariably fatal. It is known that 23 of our children (one cyanotic) survived attacks of pneumonia. Several individuals suffered repeated illnesses in early life, associated with signs of pulmonary involvement. Since there was a high incidence of lipoid pneumonia among the patients examined post mortem, it is possible that some of these children with long-continued pneumonia in early childhood had recovered from lipoid pneumonia. No death occurred from any of the infectious diseases common to childhood, including pertussis in 11 cases. Eight children had suffered from rheumatic infection.

Operative procedures were well borne, including 33 tonsillectomies and adenoidectomies (two in cyanotic individuals), one splenectomy, one mastoidectomy, one herniorrhaphy, and one open reduction for subluxation of the elbow. Death due to peritonitis followed laparotomy in a case of appendiceal abscess. In a marasmic infant, anoplasty for imperforate anus with rectovaginal fistula was followed by death from septicemia.

There are many instances of longevity among noncyanotic individuals with congenital cardiac defects, but, on the whole, the prognosis is poor for the cyanotic individual. However, since a few of them have lived long and useful lives, it is unfair to assume a hopeless prognosis in any child who has survived infancy. Cyanotic children should not be deprived of schooling.

Whether cyanosis is present or absent, there is no indication for exercise restriction beyond the limiting capacity of the heart itself. Children with congenital lesions are more fortunate than their rheumatic brothers and sisters in that they do not have the additional handicap of continued systemic and myocardial infection. In spite of startling murmurs and cardiac enlargement, the functional capacity is often normal (Table IV).

SUMMARY

A review has been made of 230 records of children with congenital cardiac defects seen at the Children's Hospital during the years 1922 to 1936. Information concerning 80 per cent of this group was obtained in 1938. One hundred two children had died, 73 per cent of the deaths occurring within the first year of life. The death rate among infants with symptoms serious enough to warrant admission to the hospital was as high as 70 per cent. One-third of the infants

who came originally under observation in the cardiac clinic had died during the period of observation. Of 94 school children, 11 per cent had died. The mortality rate observed among groups of children with congenital cardiac defects will thus be greatly influenced by the selection of patients. Impressions derived from experience with school children will be unduly optimistic.

The death rate of cyanotic infants was twice that of noncyanotic, and continued to rise progressively with age, whereas that of noncyanotic individuals tended to show only a slow increase after the second year of life.

One-half of all deaths were due to infection, with pneumonia heading the list. Among the patients that came to necropsy, 90 per cent of those with lesions of the acyanotic and delayed cyanotic type had died of infection, whereas 40 per cent of individuals with lesions of the cyanotic type had died of the cardiac defect itself.

We wish to acknowledge our indebtedness to Dr. Arthur D. Waltz and Dr. Irving J. Wolman for the privilege of reviewing the post-mortem records; and to Miss Hilda Smith and Miss Letitia Scott, without whose aid many of these children could not have been traced.

REFERENCES

1. a. Leech, C. B.: Congenital Heart Disease, J. Pediat. **7**: 802, 1935.
   b. Terplan, K., and Sanes, S.: The Incidence of Congenital Heart Lesions in Infancy. A Comparative Statistical Study Based on Postmortem Examinations, J. Tech. Methods **15**: 86, 1936.
   c. Philpott, N. W.: Relative Incidence of Congenital Anomalies in Montreal Hospitals, J. Tech. Methods **15**: 96, 1936.
   d. Nicholson, M. M.: Relative Incidence of Cardiac Anomalies Found in Autopsies Performed in Washington Hospitals, J. Tech. Methods **15**: 100, 1936.
   e. McGinn, S.: Incidence and Progress in the Recognition of Congenital Heart Disease in the Massachusetts General Hospital, J. Tech. Methods **16**: 98, 1936.
   f. Ramek, H. W., and Propst, J. H.: Incidence of Congenital Cardiac Anomalies Found at Autopsies Performed in the Hospital of the University of Pennsylvania, J. Tech. Methods **17**: 113, 1937.
   g. Szypulski, J. T.: A Study of Congenital Heart Disease at the Philadelphia General Hospital, J. Tech. Methods **17**: 119, 1937.
   h. Gibson, S., and Clifton, W. M.: Congenital Heart Disease. A Clinical and Postmortem Study of One Hundred and Five Cases, Am. J. Dis. Child. **55**: 761, 1938.
2. Irvine-Jones, E. I. M.: A Clinical Study of Congenital Heart Disease in Childhood, AM. HEART J. **2**: 121, 1927.
3. Abbott, M. E., and Dawson, W. T.: The Clinical Classification of Congenital Cardiac Disease, Internat. Clin. **4**: 156, 1924.
4. White, P. D., and Sprague, H. B.: The Tetralogy of Fallot. Report of a Case in a Noted Musician Who Lived to His Sixtieth Year, J. A. M. A. **92**: 787, 1929.
5. McGinn, S., and White, P. D.: Progress in the Recognition of Congenital Heart Disease, New England J. Med. **214**: 763, 1936.
6. Volini, I. F., and Flaxman, N.: Tetralogy of Fallot: Man Who Lived to His Forty-First Year, J. A. M. A. **111**: 2000, 1938.
7. a. Easby, M. H.: Early Recognition of Cardiac Insufficiency in Presence of Pregnancy, M. Clin. North America **21**: 1059, 1937.
   b. Townsend, C. W.: Congenital Heart Disease. Study of 30 Cases, Arch. Pediat. **16**: 680, 1899.
8. Burwinkle, quoted by Snelling, D. B.: Familial Congenital Heart Disease, J. A. M. A. **108**: 1502, 1937.
9. Abbott, M. E.: Bedside Diagnosis, p. 458, G. Blumer, Editor, Philadelphia, 1928, W. B. Saunders Company.

COMPARATIVE EFFECTS OF AMPHETAMINE SULFATE (BENZEDRINE SULFATE), PAREDRINE, AND PROPADRINE ON THE BLOOD PRESSURE

JULIUS LOMAN, M.D., MAX RINKEL, M.D.,
AND ABRAHAM MYERSON, M.D.
BOSTON, MASS.

ONE of the characteristic actions of benzedrine sulfate (phenylisopropylamine or amphetamine sulfate), a sympathomimetic amine, is to increase the blood pressure for a comparatively long period of time. For this purpose other closely related amines may prove to be as effective as, or more effective than, benzedrine sulfate. In this study, two other amines, paredrine (B-parahydroxyphenylisopropylamine) and propadrine (phenylpropanolamine hydrochloride), are compared to benzedrine sulfate in respect to their action on the blood pressure and pulse rate.

Paredrine, like benzedrine, has been noted by Alles[1] to be the most intensely active of the amines which show any appreciable degree of activity when given by mouth. Unlike benzedrine, however, its action appears to be confined practically entirely to the peripheral sympathetic mechanisms. The only previous clinical study of this drug was carried out by Abbott and Henry,[2] who found that the drug is one-fiftieth as potent as epinephrine, if given subcutaneously, and about twice as potent as ephedrine when given by mouth. With oral administration, in doses of 10 to 40 mg., these authors noted a rise in systolic blood pressure ranging from 24 to 100 mm. Hg. When given subcutaneously in doses of 10 and 40 mg., a rise in systolic blood pressure of 20 to 96 mm. Hg was observed. There was noted regularly a diminution in pulse rate with the rise in blood pressure. No definite central effects occurred following administration of the drug. The following symptoms were occasionally noted: palpitation, constriction across the chest, sweating, and mild headache.

Very little work has been done clinically with propadrine. It has been used in the treatment of allergic manifestations by Black[3] and by Boyer.[4] Chen and his co-workers[5] administered the drug orally in 50 mg. doses to two individuals and noted rises of 16 and 30 mm. Hg, respectively, in the systolic blood pressure. We are unable to find any clinical observations which have been made following the intravenous administration of either paredrine or propadrine.

From the Division of Psychiatric Research, Boston State Hospital, Boston, aided by grants from the Commonwealth of Massachusetts and the Rockefeller Foundation.
Received for publication Dec. 15, 1938.

In a recent unpublished study[6] we observed that paredrine and propadrine, in contrast to benzedrine, have little central stimulating

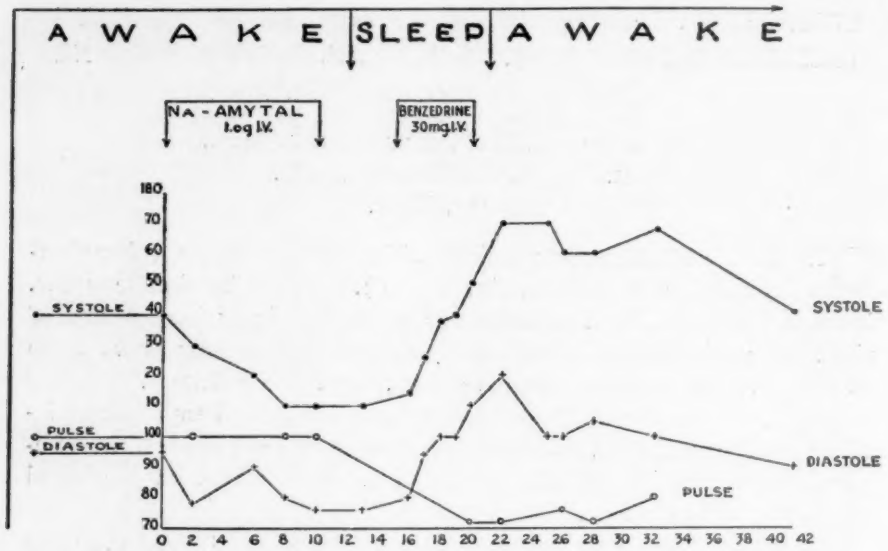


Fig. 1.—Effect of benzedrine sulfate on the narcosis induced by sodium amytal.* The patient awoke within two minutes after the end of the injection of benzedrine.

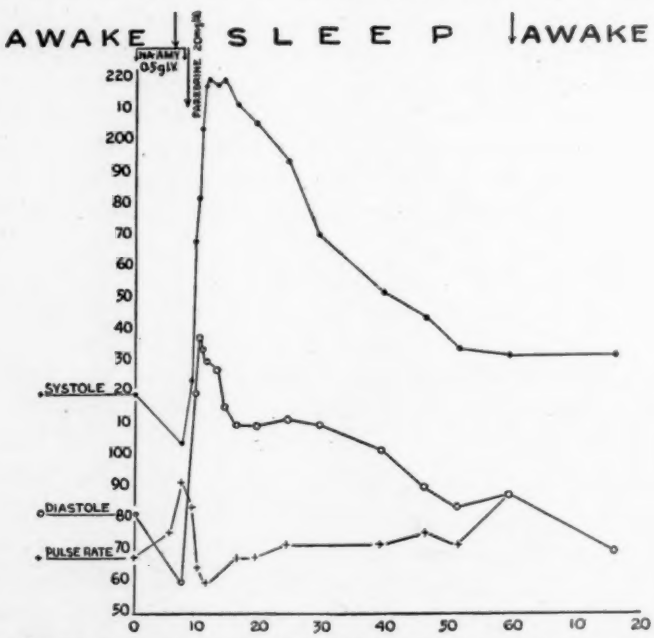


Fig. 2.—Typical effect of the administration of paredrine following administration of sodium amytal. The paredrine had no influence on the narcosis even though the blood pressure rose to a very high level following the paredrine injection.

*All drugs injected intravenously.

action, as indicated by their effects on the narcosis produced by sodium amytal (Figs. 1, 2, and 3). The counteracting effect of benzedrine on the narcosis of sodium amytal has also been noted by Reifenstein and Davidoff.[7]

A group of subjects were given intravenous injections of benzedrine in doses of 20 mg., paredrine in doses varying from 5 to 20 mg., and propadrine in doses varying from 20 to 50 mg.

Effect of Benzedrine (Ten Subjects, Table I).—Within two to fourteen minutes following intravenous injections of 20 mg. of benzedrine, the blood pressure reached its maximum, the increase varying from 30 to 56 mm. Hg. After reaching its peak, it gradually fell to its original level in 40 to 94 minutes. The pulse rate during the increase in blood pressure either remained essentially unchanged or slowed. The greatest diminution in pulse rate was 20 beats per minute. In none of the cases was any change in cardiac rhythm noted.

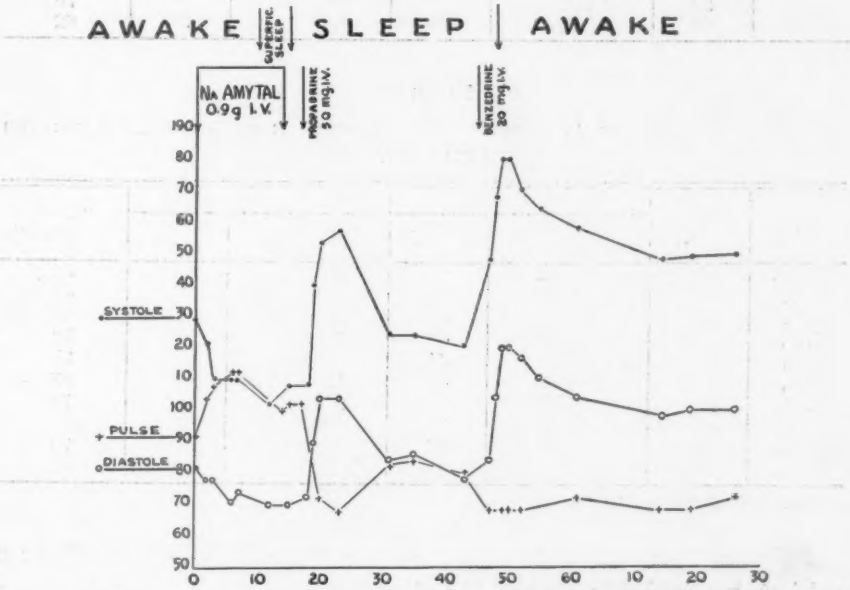


Fig. 3.—Effect of administration of propadrine following the injection of sodium amytal. The propadrine had no influence on the narcosis.

Effect of Paredrine (Ten Subjects, Table II).—Three of the ten subjects were given 20 mg. of paredrine intravenously. Because the systolic blood pressure rise was very great in these cases, namely, 56, 102, and 118 mm. Hg, respectively, smaller doses, varying from 5 to 15 mg., were employed in the other cases. With these doses the rise in systolic blood pressure varied from 28 mm. to 88 mm. Hg. The blood pressure reached a maximum in two to twelve minutes, returning to its original level in twenty to seventy minutes. In nine cases

the pulse rate became slower, the greatest change coinciding with the maximum blood pressure reading. The slowing of pulse rate varied from 4 to 32 beats per minute. In the tenth case a rise of 6 beats per minute occurred. No cardiac arrhythmias were noted in any case.

TABLE I

EFFECT OF INTRAVENOUS ADMINISTRATION OF BENZEDRINE SULFATE ON BLOOD PRESSURE AND PULSE RATE

CASE	DOSE MG.	CONTROL PERIOD		HEIGHT OF REACTION		TIME (MINUTES)
		BLOOD PRESSURE	PULSE RATE	BLOOD PRESSURE	PULSE RATE	
A. F.	20	102/68	60	150/84	60	60
E. B.	20	116/74	60	152/84	60	60
J. F.	20	130/90	74	180/110	68	40
N. K.	20	142/90	76	194/110	58	54
R. C.	20	116/70	70	148/70	68	66
E. F.	20	110/70	76	166/96	66	94
E. F.	20	118/70	76	148/96	74	74
E. J.	20	120/80	80	160/90	72	80
E. H.	20	130/70	88	178/100	68	70
E. K.	20	146/100	68	190/110	54	62

TABLE II

EFFECT OF INTRAVENOUS ADMINISTRATION OF PAREDRINE ON BLOOD PRESSURE AND PULSE RATE

CASE	DOSE MG.	CONTROL PERIOD		HEIGHT OF REACTION		TIME (MINUTES)
		BLOOD PRESSURE	PULSE RATE	BLOOD PRESSURE	PULSE RATE	
M. W.	10	122/74	88	172/100	56	58
T. F.	10	130/68	92	174/100	60	45
J. V.	20	114/60	92	170/80	60	38
E. F.	7.5	100/44	48	160/100	40	70
E. B.	15	100/82	64	198/100	52	35
E. F.	15	100/60	44	170/105	50	65
T. F.	20	118/68	72	220/90	52	70
A. F.	5	92/66	72	120/76	64	20
M. B.	15*	116/60	68	136/66	60	70
J. V.	20*	100/60	80	218/70	76	62

*By intramuscular route.

Effect of Propadrine (Twelve Subjects, Table III).—Eight of these subjects received 50 mg., and the other four, doses varying from 20 to 25 mg. The rise in systolic blood pressure in those receiving the larger doses varied between 44 and 82 mm. Hg. In three subjects who received the smaller dose, a rise in blood pressure of 16, 16, and 28 mm. Hg, respectively, occurred. In the last case no change in blood pressure occurred. The blood pressure reached its maximum one to seven minutes following the injections, and gradually fell to original levels in thirty to ninety-five minutes. The pulse diminished in rate in every case, the decrease ranging from 16 to 36 beats per minute. There was no disturbance in cardiac rhythm in any case.

TABLE III

EFFECT OF INTRAVENOUS ADMINISTRATION OF PROPADRINE ON BLOOD PRESSURE AND PULSE RATE

CASE	DOSE MG.	CONTROL PERIOD		HEIGHT OF REACTION		TIME (MINUTES)
		BLOOD PRESSURE	PULSE RATE	BLOOD PRESSURE	PULSE RATE	
M. B.	50	112/70	68	194/102	42	76
J. H.	50	116/62	88	174/106	60	80
A. McN.	50	94/62	84	160/100	48	60
T. F.	50	108/60	56	174/90	36	95
E. B.	50	116/82	64	190/100	44	90
J. V.	50	106/66	92	150/80	72	40
J. V.	25	114/70	88	130/84	72	30
M. W.	50	134/86	92	200/116	56	82
R. C.	25	116/64	68	140/80	52	46
M. B.	50	110/58	64	188/104	48	62
M. W.	20	120/78	96	120/80	92	–
M. B.	20	120/68	80	148/82	64	9

SUMMARY AND CONCLUSIONS

Benzedrine, paredrine, and propadrine have marked and rapid blood-pressure-raising effects when given intravenously. Paredrine is the most effective. Propadrine is less effective than benzedrine, doses of 50 mg. of the former drug being approximately comparable to 20 mg. of the latter. With none of the three drugs is there any disturbance in cardiac rhythm. Slowing in pulse rate usually occurs with the increase in blood pressure.

For clinical use in conditions in which rapid and prolonged blood-pressure-raising effects are indicated, any of the three amines may be chosen. The doses recommended are: for benzedrine, 20 to 30 mg.; for paredrine, 10 to 15 mg.; and for propadrine, 50 mg. Since benzedrine has a central stimulating effect, paredrine and propadrine may be preferable in certain instances.

REFERENCES

1. Alles, G. A.: The Comparative Physiological Actions of dl-Beta-phenylisopropylamines. I. Pressor Effects and Toxicity, J. Pharmacol. & Exper. Therap. **47**: 339, 1933.
2. Abbott, W. O., and Henry, C. M.: Paredrine (Beta-4 Hydroxyphenylisopropylamine) a Clinical Investigation of a Sympathomimetic Drug, Am. J. M. Sc. **193**: 661, 1937.
3. Black, J. H.: The Control of Allergic Manifestations by Phenyl-Propanol-Amine (propadrin) Hydrochloride, Journal-Lancet **57**: 101, 1937.
4. Boyer, W. E.: The Clinical Use of Phenyl-Propanol-Amine Hydrochloride (Propadrine) in the Treatment of Allergic Conditions, J. Allergy **9**: 509, 1938.
5. Chen, K. K., Wu, C. K., and Henriksen, E.: Relationship Between the Pharmacological Action and the Chemical Constitution and the Configuration of the Optical Isomers of Ephedrine and Related Compounds, J. Pharmacol. & Exper. Therap. **36**: 363, 1929.
6. Myerson, A., Loman, J., Rinkel, M., and Lesses, M. F.: The Effect of Amphetamine Sulfate (Benzedrine Sulfate) and Paredrine Hydrobromide Upon Sodium Amytal Narcosis. (To be published.)
7. Reifenstein, E. C., Jr., and Davidoff, E.: Intravenous Benzedrine Sulfate as an Antagonist to Intravenous Soluble Amytal, Proc. Soc. Exper. Biol. & Med. **38**: 181, 1938.

A NEW PRECORDIAL ELECTRODE

HARRY E. UNGERLEIDER, M.D.*
NEW YORK, N. Y.

WITH the advent of the precordial electrode, many physicians have felt that the use of the ordinary type of silver electrode necessitated having the patient, or someone else, hold the electrode in place. As this is not always convenient, a precordial lead was devised with a suction cup to hold the electrode in place.† This simple device consists of a cup made of plastic material, through which an electrode of German

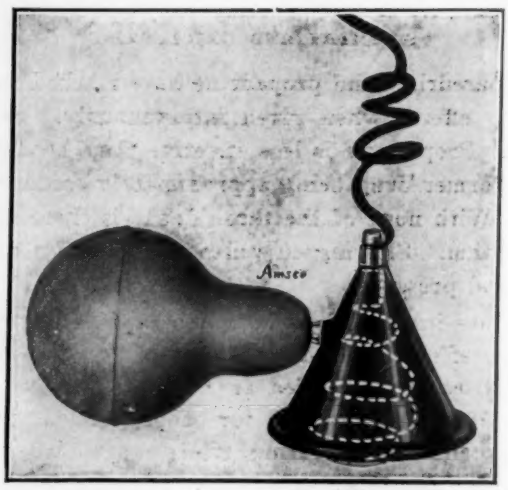


Fig. 1.

silver wire protrudes. Attached to this cup is a rubber bulb which is used to create suction sufficient to hold the electrode on the precordium, thus obviating the need of a nurse or the cooperation of the patient.

*Assistant Medical Director, Equitable Life Assurance Society.

†Manufactured by the American Medical Specialties Co., Inc., 131 East 23rd Street, New York, N. Y.

Received for publication Dec. 31, 1938.

Special Article

STANDARDIZATION OF BLOOD PRESSURE READINGS

Joint Recommendations of the American Heart Association and the Cardiac Society of Great Britain and Ireland

INTRODUCTION

IT HAS long been realized by thoughtful teachers and practitioners of medicine that the wide variations noted in blood pressure* records of the same individual were due not only to changes in the pressure from time to time under different conditions, but also to differences in the methods and interpretations used by the observers. A recent survey† revealed a serious lack of agreement among physicians as to the correct technique for measuring the blood pressure and interpreting the results obtained. Equally confusing was the situation among insurance companies as to what they should require of their examiners in this regard. Experiments with multi-aural stethoscopes demonstrated that recent years have brought little, if any, improvement in this situation, since the disagreement among the recently qualified was as great as that among attending physicians, and the range of error was too large among all groups tested. The Committees for the standardization of methods of making blood pressure readings appointed by the American Heart Association and by the Cardiac Society of Great Britain and Ireland have attempted to secure a crystallization of the best available thought on this subject.

The joint committees were asked, if feasible, to make recommendations which might be accepted as constituting standards for practicing physicians, medical teachers, insurance carriers, and all others interested in this problem. After a careful study of material available from many sources, the Committees of the American Heart Association and of the Cardiac Society of Great Britain and Ireland jointly recommend the following procedure as the standard method for taking and recording blood pressure readings in man.

STANDARDIZATION OF BLOOD PRESSURE DETERMINATIONS

Recommendations of the Committees for the Standardization of Blood Pressure Determinations

1. *Blood Pressure Equipment.*—The blood pressure equipment to be used, whether mercurial or aneroid, should be in good condition and

The recommendations contained in this report have been approved by the Association of Life Insurance Medical Directors of America.

*"Blood pressure," by common usage, signifies arterial pressure, and for that reason is so used throughout this report.

†Wright, I. S., Schneider, R. F., and Ungerleider, H.: Factors of Error in Blood Pressure Readings. AM. HEART JOUR. 16: 469, 1938.

calibrated at yearly intervals—more often if defects are suspected. (Mercurial preferred—British Committee.)

2. *The Patient.*—The patient should be comfortably seated (or lying—British Committee), with the arms slightly flexed and the whole forearm supported at heart level on a smooth surface. If readings are taken in any other position, a notation of that fact should be made. The patient should be allowed time to recover from any recent exercise or excitement. There should be no constriction of the arm by clothes, etc.

3. *Position and Method of Application of the Cuff.*—A standard-sized cuff containing a rubber bag 12 to 13 cm. in width should be used. A completely deflated cuff should be applied snugly and evenly around the arm with the lower edge about 1 inch above the antecubital space and with the rubber bag applied over the inner aspect of the arm. The cuff should be of such a type and applied in such a manner that inflation causes neither bulging nor displacement.

4. *Significance of Palpatory and Auscultatory Levels.*—In all cases palpation should be used as a check on auscultatory readings. The pressure in the cuff should be quickly increased in steps of 10 mm. Hg until the radial pulse disappears, and then allowed to fall rapidly. If the radial pulse returns at a higher level than that at which the first sound is heard, the palpatory reading should be accepted as the systolic pressure; otherwise the auscultatory reading should be accepted.

5. *Position and Method of Application of Stethoscope.*—The stethoscope should be placed over the previously palpated brachial artery in the antecubital space, not in contact with the cuff. No opening should exist between the lip of the stethoscope and the skin; this should be accomplished with the minimum pressure possible. The hand may be pronated or supinated, depending on which position yields the clearest brachial pulse sounds.

6. *Determination of the Systolic Pressure.*—The cuff should be rapidly inflated to a pressure about 30 mm. above the level at which the radial pulse can be palpated. The cuff should then be deflated at a rate of 2 to 3 mm. Hg per second. The level at which the first sound regularly appears should be considered the systolic pressure, unless, as pointed out above, the palpatory level is higher, in which event the palpatory level should be accepted. This should be noted.

7. *Determination of the Diastolic Pressure and the Pulse Pressure.*—With continued deflation of the cuff, the point at which the sounds suddenly become dull and muffled should be known as the diastolic pressure. If there is a difference between that point and the level at which the sounds completely disappear, the American Committee recommends that the latter reading should be regarded also as the diastolic pressure. This should then be recorded in the following form: RT* (or LT†) 140/80-70,

*RT = right arm.
†LT = left arm.

or 140/70-0. If these two levels are identical the blood pressure should be recorded as follows: 140/70-70. The cuff should be completely deflated before any further determinations are made.

The British Committee believes that except in aortic regurgitation it is nearly always possible to decide the point at which the change comes, and that this is the only reading which should be recorded.

EXPLANATORY COMMENTS

In addition to the above specific recommendations, the Committees believe that certain other factors should be taken into consideration by the physician who makes blood pressure determinations.

The relative merits of various types of sphygmomanometers have been the subject of numerous reports. In the opinion of the joint Committees, mercurial and aneroid types of apparatus are capable of correct readings if they are in good condition, and both types of equipment may produce inaccurate findings if not in good condition. This factor is often overlooked in the case of the mercury manometer, which should be checked at intervals as to the following points:

1. The level of the mercury at rest should be exactly at the zero mark. If some of the mercury has leaked out this will not be the case. The missing mercury should be replaced.

2. If the small air vent at the top of the glass tubing becomes clogged, a definite lag may be produced; the mercury column may not register the pressure in the bag, and the readings will therefore be incorrect.

3. The apparatus must be on a level surface, since tilting of the manometer will result in incorrect readings. It should also be level with the observer's eyes.

A yearly calibration of the aneroid type of instrument against a U-tube standard is recommended. This is particularly advisable for the older instruments, in which a sharp blow or fall may cause inaccuracies due to resultant changes in the aneroid diaphragm. The needle should stand at zero when the apparatus is completely deflated and move immediately when the inflation begins. Manometers which have a stop pin at zero, or those which have a rotatable dial, permitting the user to set the zero mark anywhere, are not recommended, since a satisfactory check with instruments of this type is impossible.

In both types of equipment the valves of the instrument, including those of the rubber bulb, should be competent and function smoothly. The entire system, including the "pressure" rubber tubing and rubber bag, must be free from leakage and must be kept in good condition. It is recommended that the instrument to be used be checked at yearly intervals against a machine known to be in perfect condition. More frequent checks should be made if the accuracy of the instrument is in doubt. The rubber cuffs should be 12 to 13 cm. wide and 23 cm. long.

The cloth covering should be of inextensible material of such a nature that even pressure is exerted throughout the width of the cuff; it should extend as a band 15 cm. wide for 60 cm. beyond the edge of the rubber cuff, and then taper gradually for an additional 30 cm. New types of cuff, using a "zipper" mechanism or hooks on a rib extending the width of the cuff, appeared to be more satisfactory than the long, tapering cuff end. If bulging occurs above and below the band the reading may not be accurate.

A special cuff should be used to measure blood pressure in the leg. The rubber bag should be 15 cm. wide, and its covering 17 cm. wide and 30 cm. longer than in the case of the armlet (total 120 cm.). For children, cuffs of the following widths have been suggested: under eight years, less than 9 cm.; under four years, less than 6 cm.; newborn babies, less than 2½ cm. The limited work done in this field does not warrant a definite recommendation at this time.

The American Committee selected the sitting position as the preferable one because of the fact that it simplifies the taking of large numbers of blood pressure readings. It is true that many patients are bedridden, but in most instances they may be propped up into a sitting position without causing more than transitory disturbances in the circulation; and when this is impossible it is suggested that a notation be made as to the position in which the blood pressure is taken. The British Committee did not think that there was any significant difference between the sitting and lying positions. For blood pressure readings in the thighs, the stethoscope bell should be placed over the popliteal artery with the patient prone.

Certain physical and psychologic factors should be considered. Inquiry should be made as to the patient's activity just before the examination. Exercise and meals affect the blood pressure. A rest period of from 10 to 15 minutes prior to the making of the observations will eliminate or minimize certain of these factors. It is important that the physician evaluate the degree of stress or emotional crises through which the patient may be passing. The first reading taken by a physician is often much higher than later ones, due to apprehension and nervousness on the part of the patient. It is often wise, therefore, to avoid conclusions regarding the blood pressure level of an individual until several readings have been made on successive visits. This is especially important with hypertensive and hyperthyroid patients. Any evidence of apprehension or of undue concern on the part of the physician may alarm the patient and increase the pressure.

There are variations in the blood pressure level of certain individuals in the course of a day. It is therefore suggested that for careful records the time of the day should be noted, and if the patient is being carefully followed with reference to the blood pressure level the observations

should be made at essentially the same time and in the same relationship to meals, sleep, exercise, and other similar factors.

The term "points" is suggested for use in reference to diastolic pressure, since the word "phase," formerly used, implies a measure of time interval, whereas in reality the fourth and fifth "points" are the exact levels at which change is made from one phase to the next. Detailed discussion of the second and third phases is not pertinent to this report, since those phases are of little, if any, practical importance and tend to confuse the issue at hand. It should be clearly recognized that a single figure for systolic or diastolic pressure apparently does not represent actual pressure within from 5 to 10 mm. of mercury. If the physician wishes to minimize the sources of error several blood pressure readings should be made, the highest and lowest being recorded. Although an average of the series of readings might be recorded, this would not have the same significance in instances of cardiac irregularity.

The determination of blood pressure in arrhythmias is unsatisfactory, at best, when made with the apparatus under discussion. With premature beats the higher systolic pressure of the beats that terminate compensatory pauses should be ignored. With auricular fibrillation both diastolic and systolic readings should be recorded as approximate only. It is suggested that in this condition the average of a series of readings for the appearance of the first sound be noted as the systolic pressure, and that similar averages for the fourth and fifth "points" be recorded as the diastolic pressure. The diagnosis, if not stated elsewhere on the patient's chart, should be noted with the blood pressure recording. In aortic regurgitation with a collapsing pulse the diastolic end point is sometimes marked by a less obvious change in the quality of the sounds than normally. This change may be difficult to appreciate.

Alternation of the pulse during blood pressure determinations may indicate left ventricular weakness.

It is suggested that, when especially careful studies of the blood pressure are to be made, the use of basal blood pressure conditions should be considered. A preparation similar to that used prior to measuring the basal metabolic rate is recommended. Such a basal blood pressure determination should be made 10 to 12 hours after a meal (preferably in the morning), after the patient has rested for 30 minutes in a comfortably warm room. The patient should be mentally, as well as physically, at ease. This procedure would be most useful in experimental studies in which an accurate standard level is desired. Objections to its use in general practice are obvious.

When auscultatory methods alone are used, the actual blood pressure level may be definitely higher than the level at which the first sounds are detected. Under these circumstances, the palpatory reading will be the more nearly correct of the two. If both palpatory and auscultatory methods are used, as recommended, this error will be detected.

In occasional instances, the usual sounds are heard over the brachial artery at a fairly high level; as the pressure in the cuff is reduced, the sounds completely disappear, only to reappear at a distinctly lower level. This zone of silence is known as the auscultatory gap. Its existence is obviously important, inasmuch as it is possible in such patients to inflate the cuff only to the level of the auscultatory gap, and to record the systolic pressure at the level where sounds are first heard, which may actually be 40 or 50 mm. below the true systolic level.

The importance of avoiding unnecessary venous congestion should be recognized. This can be minimized by making certain that there are no constricting bands on the patient's arm, and that the pressure cuff is not kept inflated longer than absolutely necessary to make the blood pressure reading. Decompression should be at the rate of approximately 2 to 3 mm. Hg per second. After making a reading, the cuff pressure should be reduced to zero long enough to allow the veins to empty before another determination is started.

It is suggested that on the first examination of the patient the blood pressure be taken in both arms, since the two may not be the same. If the patient is followed for a period of time this procedure might wisely be repeated at stated intervals of every few months, and at other times if indicated by developments. In the presence of unexplained high pressure in the brachial arteries it is suggested that the blood pressure in the legs be taken also. By this procedure conditions such as coarctation of the aorta may be detected.

If the variations in blood pressure which occur with respiration are considerable, this factor may be eliminated by taking a reading while the patient holds his breath at midrespiration, but this must be for only a short interval, or abnormal blood pressure readings, due to asphyxia and other factors, will result.

Certain factors inherent in the physician, such as variations in accuracy of hearing, must be recognized as important. A physician who is aware that his hearing has become impaired should use a stethoscope in which sound is amplified to a considerable extent, and in the event of marked deafness electrically amplified or other mechanical devices should be utilized. It is thought inadvisable at this time to make recommendations regarding automatically recording blood pressure equipment.

The combined use of the auscultatory and palpatory methods, as described herein, will yield routine data that are as reliable as those given by any other method. Under exceptional circumstances, as when the pulse is too feeble to produce sounds or too irregular for averaging, recording methods may become necessary. Those contemplating the use of graphic methods should first ascertain through reliable sources whether they will subserve the ends in mind.

The recommendation of a standard procedure, as outlined by the Committees, is not intended to discourage initiative when indicated in special situations.

M. H. BARKER, Chicago, Ill.
JOSEPH ERLANGER, St. Louis, Mo.
JONATHAN MEAKINS, Montreal, Can.
RALPH SCHNEIDER, New York, N. Y.
S. B. SCHOLZ, JR., Philadelphia, Pa.
HARRY UNGERLEIDER, New York, N. Y.
PAUL D. WHITE, Boston, Mass.
CARL WIGGERS, Cleveland, Ohio
IRVING WRIGHT, New York, N. Y., Chairman

Committee for the Standardization of Blood Pressure Readings of the American Heart Association

CRIGHTON BRAMWELL, Manchester, England
T. F. COTTON, London, England
WILLIAM EVANS, London, England
A. R. GILCHRIST, Edinburgh, Scotland
JOHN HAY, Liverpool, England
MAURICE CAMPBELL, London, England, Chairman

Committee for the Standardization of Blood Pressure Readings of the Cardiac Society of Great Britain and Ireland

Department of Clinical Reports

AURICULAR FIBRILLATION OF TWENTY-TWO MONTHS' DURATION, WITH RETURN TO NORMAL SINUS MECHANISM WITHOUT THE AID OF QUINIDINE

GEORGE E. BURCH, M.D.
NEW ORLEANS, LA.

SEARCH of the literature failed to reveal a report of a single case of auricular fibrillation of long duration in which reversion to normal sinus mechanism occurred without the use of quinidine or related drugs. Bishop[1] reports four patients whose auricular fibrillation was supplanted by normal sinus mechanism without the aid of specific therapy. In two of the patients electrocardiograms are presented which demonstrate the existence of auricular fibrillation and normal sinus mechanism. The abnormal and normal mechanisms were recorded at approximately two- and three-year intervals, respectively. In neither instance, however, is it stated whether or not the fibrillation was continuous throughout this time. The histories would suggest that both patients might have been suffering from paroxysms of fibrillation. Again, there is no indication that either patient was seen at frequent intervals, so that possible changes in rhythm could have been detected.

Paroxysmal auricular fibrillation of short duration, especially in patients with hyperthyroidism, is well known.[2, 3, 4] Again, auricular fibrillation of long duration, fifteen years, or more, without return to normal mechanism, has been reported.[2, 5] Kohn and Levine[6] described twenty patients with auricular fibrillation of over one year's duration. With the aid of quinidine fifteen of these regained normal sinus mechanism. Similar experiences have been reported by others.[7, 8] However, the patient to be described is unique in that he had had auricular fibrillation (verified by electrocardiograms) continuously for 22 months, at the end of which time normal sinus mechanism returned without the aid of quinidine or related drugs.

CASE REPORT

M. S., a white man, 61 years of age, entered the Outpatient Department of Charity Hospital May 18, 1935, complaining of dyspnea, edema of the feet, weakness, and palpitation. The patient had been suffering from mild dyspnea on marked exertion for several weeks, but with sudden muscular exertion the day before enter-

From the Department of Medicine, School of Medicine, Tulane University of Louisiana, and the Charity Hospital of Louisiana, New Orleans.
Received for publication Dec. 9, 1938.

ing the clinic he suddenly experienced palpitation, faintness, and extreme dyspnea. On admission to the clinic, the patient's palpitation and dyspnea had decreased, but edema had developed progressively in the legs and feet. On examination the patient was found to have an absolute irregularity of his pulse, generalized senile arteriosclerosis, a heart rate of 108 per minute, and a blood pressure of approximately 180/110.

The heart was enlarged, and there was a soft, blowing, systolic, mitral murmur. There were fine moist râles in the bases of both lungs. The liver was enlarged, and there was edema of both legs and feet. The blood Wassermann reaction was found to be strongly positive. An electrocardiogram showed auricular fibrillation (Fig. 1), and a teleoroentgenogram showed that the heart was enlarged; the transverse diameter of the heart was 17.8 cm., the transverse diameter of the thorax 31 cm., and the longitudinal diameter of the heart 17.6 cm. Other laboratory studies failed to show anything significant.

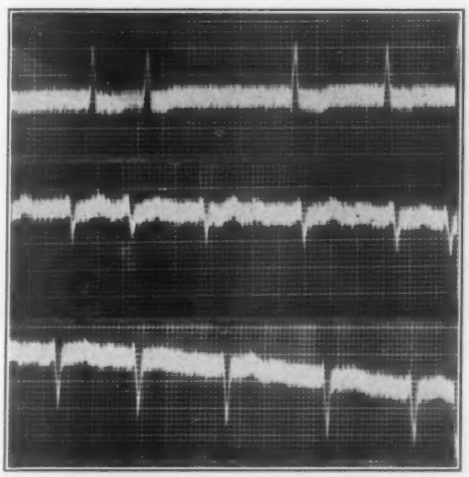


Fig. 1.—Electrocardiogram showing auricular fibrillation, taken May 18, 1935.

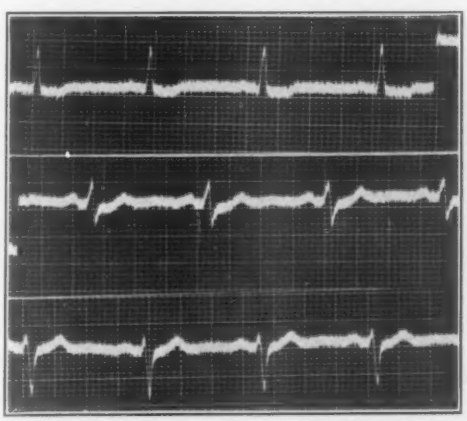


Fig. 2.—Electrocardiogram showing normal sinus mechanism, taken March 26, 1937.

The patient was digitalized. Twenty-five drops of the standard tincture, three times daily, were found necessary for maintenance. Since the patient was suffering

from rather severe congestive heart failure, but would not be admitted to the hospital and, therefore, could be seen only at relatively long intervals, quinidine was not administered. Antisyphilitic treatment was started. Arsenical preparations were not employed until he had received mild antisyphilitics for many months.

Progress.—The patient was seen at weekly intervals for a few months, and every two weeks thereafter. He responded rapidly to treatment, but his auricular fibrillation continued. The ventricular rate was reduced to 70-80 per minute. A few weeks after digitalization was established, 30 drops of standard tincture of digitalis, three times daily, were found necessary for maintenance.

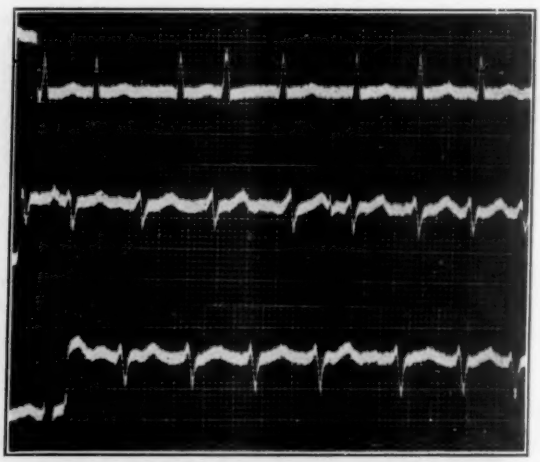


Fig. 3.—Electrocardiogram showing auricular fibrillation, taken Jan. 5, 1938.

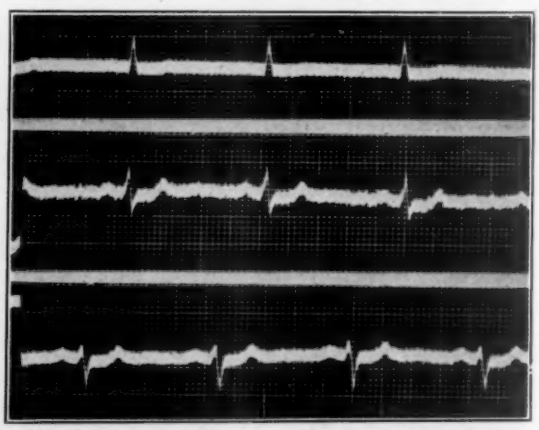


Fig. 4.—Electrocardiogram showing normal sinus mechanism, taken Sept. 14, 1938.

The electrocardiogram, from time to time, showed no definite differences from the original, except that the ventricular rate had been slowed. On March 26, 1937, the patient's radial pulse and heartbeat were found to be regular. All previous evidences of auricular fibrillation had disappeared. An electrocardiogram revealed normal sinus mechanism (Fig. 2). The cardiac mechanism remained normal until Jan. 5, 1938, when clinical evidence of auricular fibrillation reappeared, and its presence was verified by an electrocardiogram (Fig. 3). On Feb. 3, 1938, the blood

Wassermann reaction was found to be negative, and has remained so since. The patient's state remained uneventful until Sept. 14, 1938, when his pulse and heartbeat again became regular and slow, and his blood pressure dropped to 110/60. The patient's blood pressure previously had never been below 160/100. The blood pressure measurements were only approximate during the periods of fibrillation. An electrocardiogram at this time showed normal sinus mechanism (Fig. 4), and in the teleoroentgenogram the cardiac measurements were as follows: transverse diameter of the heart, 11 cm.; longitudinal diameter of the heart, 13 cm.; diameter of the great vessels, 8 cm., and transverse diameter of the thorax, 32 cm. The patient was instructed to reduce the dose of his digitalis to 25 drops, three times daily. Another electrocardiogram, made on Sept. 21, 1938, showed frequent premature ventricular contractions. However, one week later these premature contractions had disappeared and normal sinus mechanism persisted.

For forty weeks the patient received continuous antisyphilitic treatment, consisting of courses of mercury rubs, potassium iodide, and 55 intramuscular injections of bismuth preparations and 59 of bismarsen, the latter being given during the final weeks of his treatment.

COMMENT

This patient was definitely known to have had auricular fibrillation for twenty-two months. The diagnosis was sustained by electrocardiograms taken May 18, 1935, when the patient was first seen, and at frequent intervals until March 26, 1937, when normal sinus mechanism was detected. It would be impossible to determine the length of time the patient had suffered from auricular fibrillation prior to his first visit to the Charity Hospital Outpatient Clinic, as he had not seen a physician for a number of years previous to the onset of his present illness. His history would suggest, however, that the auricular fibrillation probably began the day before he entered the medical clinic, when sudden physical exertion precipitated the acute attack of dyspnea and palpitation. The latter symptom persisted; it was the first such attack the patient had ever experienced.

Many factors have been alleged to favor the persistence of auricular fibrillation, viz., focal infections, general diseases, local strain of muscles or joints, painful conditions, like stones in the kidneys or gall bladder, and heart failure.[5] There appears to be no relationship between the syphilitic infection and the behavior of the abnormal cardiac mechanism. Auricular fibrillation is known to be rare in syphilitic heart disease. Furthermore, there was no clinical evidence that syphilis was an active etiologic factor in producing the heart disease. The systemic syphilitic infection, acting as a "general disease," might possibly favor the persistence of auricular fibrillation, but this is not likely, as the auricular fibrillation had ceased for a period of nine months and had returned again before the blood Wassermann reaction became negative. It is extremely doubtful whether the syphilitic infection played a significant role in influencing the behavior of the cardiac mechanism.

Congestive heart failure might influence the duration of auricular fibrillation, but this was apparently not a factor in our case, for the patient's heart failure had completely disappeared many months before normal sinus mechanism returned. Furthermore, the cardiac mechanism changed from auricular fibrillation to normal sinus mechanism, back to fibrillation, and again to normal sinus mechanism, without any evidence that the patient had congestive heart failure.

Digitalis has been reported to restore normal mechanism when administered in large single doses shortly after the onset of the auricular fibrillation.[9] On the other hand, the drug has also been said to bring on auricular fibrillation.[10] It is quite unlikely that the digitalis administered to this patient influenced the auricular fibrillation, except by slowing the ventricular rate, for the abnormal mechanism started before the patient had received any digitalis, and the cardiac mechanism reverted to normal, then to fibrillation, and back to normal, while he was still under the influence of digitalis. Therefore, it cannot safely be said that the reversion of the cardiac mechanism to normal was related to digitalis.

The decrease in cardiac size is of interest. In spite of the many months of auricular fibrillation, the cardiac size decreased from a state of definite enlargement to within the limits of normal. Auricular fibrillation might produce slight cardiac enlargement,[5] but it is doubtful whether it would favor its disappearance. The observations of Stewart, et al.,[11] show that digitalis will decrease the cardiac size in patients with auricular fibrillation and congestive failure. Whether this factor alone is sufficient to explain the pronounced decrease in cardiac size in this patient can only be conjectured, although it was probably one of the contributing factors. The reduction in cardiac size probably indicates, also, a decrease in cardiac strain, or a repair of an abnormal myocardial state independent of the strain, or both. The mechanism of the decrease in cardiac size remains obscure, as well as its relationship to the abnormal cardiac mechanism.

A satisfactory explanation for the behavior of the cardiac mechanism cannot be advanced at the present time. The patient will continue under observation, during which time etiologic factors responsible for the arrhythmia will be sought.

SUMMARY

The case of a patient with definite auricular fibrillation of 22 months' duration, in which cardiac mechanism returned to normal without the aid of quinidine or related drugs, is presented. Apparently, no such case has been reported previously. Factors possibly influencing the disturbed cardiac mechanism are discussed.

REFERENCES

1. Bishop, L. F.: Fibrillation of the Auricle Returned to Normal Rhythm, Am. J. M. Sc. **165**: 29, 1923.
2. Evans, W. A.: Long-Standing Cases of Auricular Fibrillation With Organic Heart Disease; Some Clinical Considerations, Ann. Int. Med. **9**: 1171, 1936.
3. Williams, F. A.: Auricular Fibrillation and Life Expectancy, Minnesota Med. **3**: 365, 1920.
4. Phillips, J., and Anderson, J. P.: Cardiac Disturbances in Goiter, J. A. M. A. **89**: 1380, 1927.
5. White, P. D.: Heart Disease, Ed. 2, New York, 1937, The Macmillan Company.
6. Kohn, C. M., and Levine, S. A.: An Evaluation of the Use of Quinidine Sulfate in Persistent Auricular Fibrillation, Ann. Int. Med. **8**: 923, 1935.
7. Orgain, E. S., Wolff, L., and White, P. D.: Uncomplicated Auricular Fibrillation With Auricular Flutter, Arch. Int. Med. **57**: 493, 1936.
8. Viko, L. E., Marvin, H. M., and White, P. D.: A Clinical Report on the Use of Quinidine Sulphate, Arch. Int. Med. **31**: 345, 1923.
9. Schwartz, S.: The Effects of Digitalis on Premature Auricular Contractions Associated With Attacks of Paroxysmal Auricular Fibrillation. The Use of the Drug in the Treatment and Prevention of Certain Forms of These Arrhythmias, AM. HEART J. **6**: 458, 1930-31.
10. McEachern, D., and Baker, B. M., Jr.: Auricular Fibrillation; Its Etiology, Age Incidence and Production by Digitalis Therapy, Am. J. M. Sc., **183**: 35, 1932.
11. Stewart, H. J., Deitrick, J. E., Crane, N. F., and Wheeler, C. H.: Action of Digitalis in Uncompensated Heart Disease, Arch. Int. Med. **62**: 569, 1938.

COMPLETE TRANSPOSITION OF THE AORTA AND PULMONARY ARTERY

In One Case, With Patent Ductus Arteriosus and Foramen Ovale, and, in Another, With Interventricular Septal Defect and Pulmonic Stenosis

Bianca R. Lia, M.D., and Olga C. Leary, M.D.
Boston, Mass.

IN HER analysis of 1000 cases of congenital heart disease, Maude Abbott[1] found only thirty-eight cases of complete transposition of the great vessels associated with patency of the ductus arteriosus and foramen ovale. The association of complete transposition with interventricular defect occurred in thirty-six cases, only seventeen of which were analyzed. Because of the comparative rarity of this lesion, two additional cases are here reported.

Case 1.—Baby Boy D, 3 weeks old, only child of normal white parents, was born Dec. 3, 1937, after an easy breech delivery, and was transferred from the nursery to the children's ward on Dec. 27, 1937. He showed cyanosis and labored breathing from birth, at which time there was considerable mucus in the respiratory tract. Physical examination revealed a well-nourished, well-developed male infant, appearing very cyanotic and dyspneic. The blueness was generalized, more marked in the circumoral and nasal regions and less in the fingers and toes, and became less intense after crying. The cry was strong, the muscle tone good, and the baby was active and responsive. There was a soft systolic murmur at the mitral area, transmitted to the axilla and up the sternum. This murmur was discovered Dec. 7, 1937, at which time it was heard over the entire precordium, loudest under the sternum at the second intercostal space. The spleen was palpable two fingerbreadths below the costal margin. The temperature varied between 99° and 100° F.; the pulse rate was about 90 until the last few days, when it rose to 140-150.

Laboratory Findings

Dec. 6, 1937		
	Erythrocyte count,	3,500,000
	Hemoglobin,	85 per cent
	Leucocyte count,	20,150
	Neutrophils,	65 per cent
	Lymphocytes	34 per cent
	Monocytes	1 per cent
Dec. 28, 1937		
	Erythrocyte count,	3,710,000
	Hemoglobin,	65 per cent
	Leucocyte count,	11,950
	Neutrophils,	25 per cent
	Lymphocytes	73 per cent
	Monocytes	2 per cent

From the Department of Roentgenology and Pathology of the New England Hospital for Women and Children.
Received for publication Dec. 9, 1938.

The urine was normal. The mother had a negative Hinton test. The electrocardiogram was interpreted as follows:[2] "Normal rhythm at a rate of 170. The P waves are of short duration and sharply peaked in Leads II and III. The P-R interval is 0.1 second. The QRS complexes are normal in duration and amplitude, but there is marked right axis deviation. The S-T segments are slightly elevated in all leads. The T waves are normal and upright in Leads I and II and slightly inverted in Lead III. Lead IV is normal. This electrocardiogram is consistent with the diagnosis of congenital heart disease."

Roentgenologic study a few hours after birth revealed no enlargement of the cardiac shadow as a whole, though the elevation of the apex suggested hypertrophy of the right ventricle (Fig. 1). The lungs appeared incompletely aerated. A repeat examination, with fluoroscopy, nine days later, however, showed a definite increase in the size of the heart (Fig. 2). The enlargement appeared to be due both to auricular dilatation and ventricular hypertrophy and dilatation. The appearance was that of congenital cardiopathy. The aortic shadow seemed small. The lesion suggested was patent ductus arteriosus.

After delivery the infant lived in an oxygen tent. Carbon dioxide was given at frequent intervals, as well as coramine and other respiratory stimulants. There was no difficulty in feeding until the terminal stage, beginning Dec. 28, 1937. The general condition became progressively worse, the respirations more labored, irregular, and slower. The cyanosis increased. There was no response to stimulation, and the baby died Jan. 1, 1938.

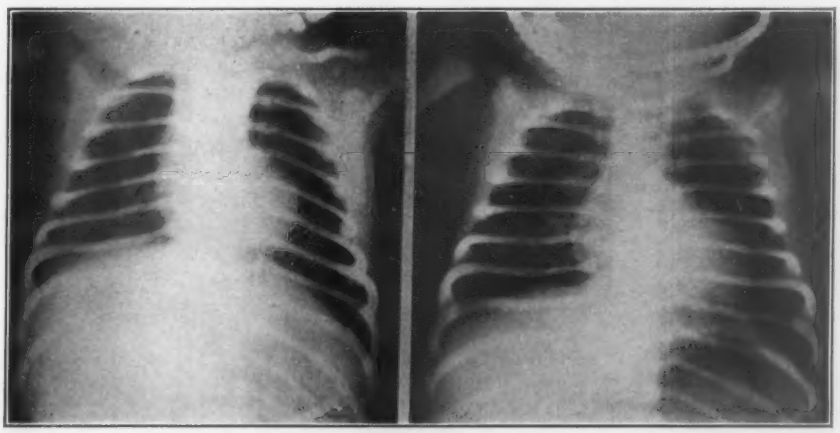


Fig. 1. Fig. 2.

Fig. 1.—Case 1, Dec. 4, 1937. Note normal size of cardiac shadow and elevation of apex.

Fig. 2.—Case 1, Dec. 13, 1937. The heart has enlarged since the previous examination.

The post-mortem findings relative to the heart were as follows: The heart was large, measuring 6.5 cm. transversely. The thoracic cage at the same level measured 10 cm. The heart showed two ventricles and two auricles with pulmonary veins and venae cavae entering in the normal manner. The right ventricle was very large and relatively thick-walled. The aorta arose from the right ventricle, and the innominate, left subclavian, and left common carotid arteries arose in the usual manner from the aortic arch. The pulmonary artery arose from the left ventricle, and divided into right and left branches. The ductus arteriosus was widely patent. The foramen ovale was also patent. There was no ventricular defect. The valves were normal (Figs. 3, 4, 5).

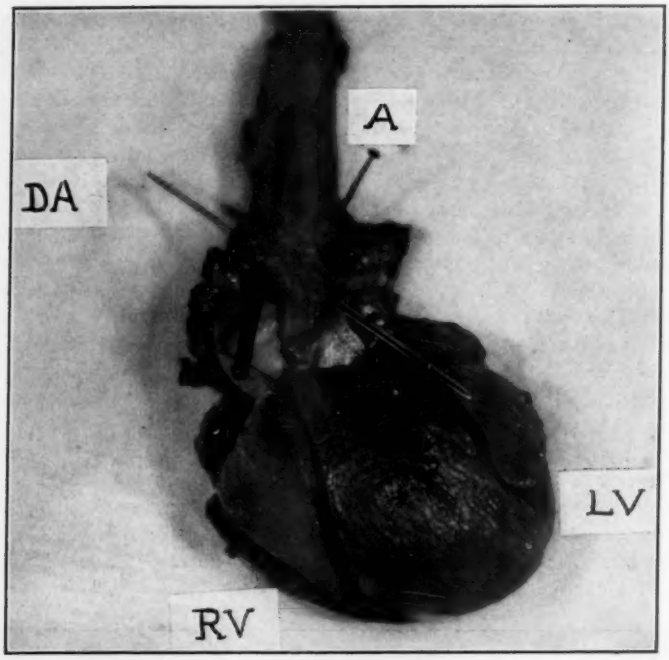


Fig. 3.—Case 1, DA—Ductus Arteriosus; A—Aorta; RV—Right Ventricle; LV—Left Ventricle. Dark probe extends through aortic valve into aorta; glass probe goes through ductus arteriosus.

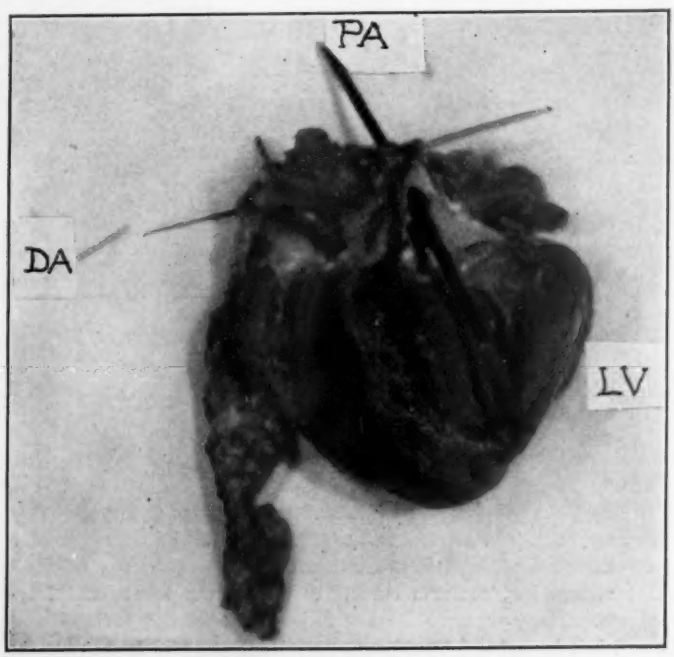


Fig. 4.—Case 1, PA—Pulmonary Artery; DA—Ductus Arteriosus; LV—Left Ventricle. Dark probe goes from left ventricle into pulmonary artery.

The heart weighed 55 gm. The wall of the left ventricle measured 4 mm., the wall of the right ventricle 5 mm., the mitral valve 3.5 cm., the aortic valve 2.4 cm., the pulmonary valve 2 cm., and the tricuspid valve 4.2 cm.

The complete pathologic diagnosis was: (1) Congenital anomaly of the heart, namely, transposition of the aorta and pulmonary arteries, patent ductus arteriosus, and patent foramen ovale; (2) extreme hyperemia, universal; (3) atelectasis of the lungs; and (4) hemorrhage into the lungs, intestines, and pancreas.

Fig. 5.—Case 1, Patent foramen ovale visualized.

CASE 2.—Baby Robert O, 8 weeks old, was readmitted to the children's ward Aug. 18, 1938, because of "stiffening of the limbs," a "queer cry," and cyanosis from birth. Delivery on June 21, 1938, was an easy left occipitoanterior with labor lasting five hours. The baby's color was dusky bluish. At that time examination revealed a loud systolic murmur all over the precordium. Because of vomiting after feeding, he was transferred to the children's ward July 5, 1938. With this regurgitation he had attacks of very rapid and irregular respiration (rate 24-38), with a pulse rate between 120 and 160. On discharge, July 24, 1938, he had gained 7 oz. in weight. There was no vomiting, but he was still blue, and his respirations were rapid and irregular. On re-entry there were marked cyanosis, tetanic spasm, a rapid pulse rate, and marked dyspnea. The cardiac murmur was not as distinct as before. The aortic second sound was louder than the pulmonic second. He was placed in an oxygen tent and given codeine and digitalis, but he rapidly became more cyanotic. He assumed an opisthotonos position. His respiratory rate increased (40-72), then the pulse and respirations slowed and ceased on Aug. 20, 1938.

Laboratory Findings

Hemoglobin,	70 per cent
Erythrocyte count,	4,780,000
Leucocyte count,	6,450
Neutrophils,	11 per cent
Large lymphocytes,	4 per cent
Small lymphocytes,	67 per cent
Monocytes,	14 per cent
Eosinophils,	3 per cent
Basophils,	7 per cent

The electrocardiogram showed[2] "normal rhythm at a rate of 160 a minute. The P waves are normal, but sharply peaked in Lead II, and the P-R interval is 0.13 second. The QRS complexes are normal in amplitude and duration, but their chief wave is downwardly directed in all leads. This results in an extreme degree of right axis deviation. The S-T segments are slightly elevated in all leads. The T waves are upright and normal in all three leads."

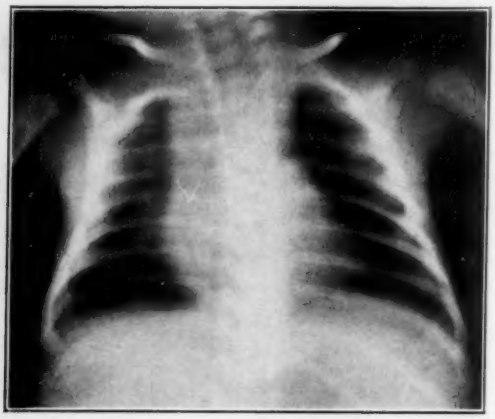


Fig. 6.—Case 2. Note widened supracardiac shadow and enlargement to the right of the right auricle.

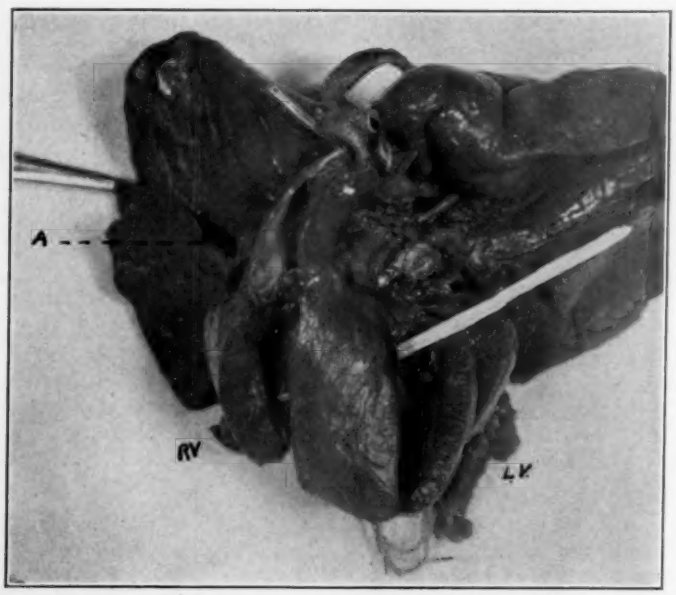


Fig. 7.—Case 2. A—Aorta; glass probe in ductus arteriosus; probe through interventricular septal defect.

Roentgenologic study revealed no definite enlargement of the cardiac shadow. The supracardiac shadow was broadened and more prominent on the right side; there was also widening in the region of the right auricle (Fig. 6).

Post-mortem examination revealed the following findings:

The thymus weighed 7 gm.; it was pink and soft, with moderately engorged vessels. The heart appeared very large; it measured 5 cm. transversely at the auriculoventricular junction; the right auricle was widely distended with blood and soft clot. The aorta arose from the right ventricle, measuring 1.3 cm. in diameter at ascending arch. The innominate, left common carotid, and left subclavian arteries arose normally from the arch. The ductus arteriosus was patent, but contained some firm clot. The pulmonary artery was relatively small, 8 mm. in diameter; it divided normally into right and left branches. The pulmonary valve had but two cusps. At the base of the pulmonary valve there was a small pouch-like structure, 5 mm. in diameter, beneath which there was a large, round opening, 7 mm. in diameter, between the ventricles. The foramen ovale was closed by a fenestrated membrane, leaving, however, an easily dilatable channel through which a probe was readily passed from right to left auricle.

The wall of the right ventricle measured 6-7 mm., that of the left ventricle 4 mm., the mitral valve 3 cm., the aortic valve 2.5 cm., the pulmonary valve 8 mm., and the tricuspid valve 4 cm. The right and left subclavian veins were much dilated.

Diagnosis.—Transposition of the great vessels; pulmonic stenosis; defect in the interventricular septum; early lobular pneumonitis; universal passive congestion.

In the study of congenital heart disease the roentgenologic examination has not yet proved as exact a diagnostic procedure as it is for other cardiac lesions. For this reason, any case in which autopsy findings can be correlated with roentgenologic studies may lead to more accurate knowledge. In Case 1, the first examination showed an apparently normal cardiac outline. The second, nine days later, however, revealed enlargement in the transverse diameter and length. This enlargement was not globular; it was definitely more prominent on the left side. The measurements were as follows:

Dec. 4, 1937		*Dec. 31, 1937*	
Right median,	2.05 cm.	Right median,	2.4 cm.
Left median,	2.4	Left median,	3.5
Transverse,	4.45	Transverse,	5.9
Pulmonary field,	11.1	Pulmonary field,	11.1

The auricular shadows bulged into the posterior mediastinal space. The aortic shadow remained small. Post-mortem examination showed that the enlargement was due to hypertrophy and dilatation of the right ventricle, with dilatation of all other chambers. It is interesting to note that at birth the diagnosis of atelectasis was suggested because of the large amount of mucus in the trachea and the absence of physical signs of heart disease. Yet the cyanosis at that time was greater than is consistent with the degree of incomplete aeration revealed by the first roentgenogram. Later, both clinical and roentgenologic findings pointed to definite congenital cardiopathy. On the other hand, in Case 2 no cardiac enlargement was demonstrated, either roentgenologically or by physical examination. There is a possibility that the broadened supracardiac shadow represented the dilated subclavian veins and the trans-

posed blood vessels. The marked cyanosis, dyspnea, and loud systolic murmur made the diagnosis of congenital heart disease definite. In both of these patients an enlarged right ventricle was found at post mortem, yet the cardiac outlines were not similar and did not show the "coeur en sabot" contour that has been regarded as evidence of right ventricular enlargement.[3]

SUMMARY

This is a report of two cases of complete transposition of the great vessels, associated, in one case, with patency of the ductus arteriosus and foramen ovale, and in the other, with an interventricular septal defect and pulmonic stenosis. Both patients were studied clinically, roentgenologically, and by post-mortem examination.

REFERENCES

1. Abbott, Maude E.: Atlas of Congenital Heart Disease, The American Heart Association, New York, 1936.
2. Graybiel, Ashton: Personal Communication.
3. White, Paul D.: Heart Disease, Chapter 12, New York, 1937, Macmillan Company.

PAROXYSMAL BUNDLE BRANCH BLOCK CONVERTED INTO TWO-TO-ONE BUNDLE BRANCH BLOCK BY MEANS OF ATROPINE

CASE REPORT*

NORMAN H. BOYER, M.D.
CLEVELAND, OHIO

THE question whether or not the main branches of the His-Tawara bundle are subject to the influence of the vagus nerves is as yet unsettled. Drury and Mackenzie[1] were unable to demonstrate any effect on branch conduction, either by the use of acetylcholine or by stimulation of the vagi in the neck, in normal dogs. If, however, either the right or the left branch was injured mechanically, bundle branch block complexes appeared in the electrocardiogram for a short period of time, after which what appeared to be full recovery occurred. At a critical period following this recovery, bundle branch block complexes could be made to *reappear* by stimulation of the vagi in the neck. The authors attributed this effect to action of the vagus on the junctional tissues, rather than on the bundle branches. They thought that vagal stimulation increased the "decrement" through the A-V node and the main bundle, and consequently the impulse arrived at the still partially damaged branch too weak to pass, whereas it passed the undamaged branch readily.

This report deals with a patient, one of whose bundle branches was damaged but was still capable of fluctuation in conductivity.

CASE REPORT

Mrs. J. W., a 64-year-old white woman, entered the Evans Memorial Hospital complaining of weight loss, palpitation, and nervousness, of six months' duration. Aside from mild dyspnea on exertion and palpitation, there had been no significant cardiorespiratory symptoms. The past history was irrelevant. Physical examination revealed an adenomatous thyroid and signs of hyperthyroidism. The heart was not enlarged, and its action was rapid but regular. There was a precordial systolic murmur. The blood pressure was 170/95. There was moderate peripheral arteriosclerosis.

Laboratory Findings.—A roentgenogram of the chest showed compression of the trachea by the thyroid gland; the heart was normal in size and contour, the aorta long and tortuous; the lungs were clear. The urine was normal. Morphologically, the blood cells were normal. The blood Wassermann and Kahn reactions were negative. The vital capacity was 1500 c.c. The basal metabolic rate ranged from plus 30 per cent to plus 40 per cent on repeated determinations.

Electrocardiograms.—At the time of admission to the hospital the electrocardiogram was normal save for inversion of the T wave in Lead IV. The heart rate was

*From the Evans Memorial of the Massachusetts Memorial Hospitals, Boston.
Received for publication Dec. 16, 1938.

then 103 per minute. Two days later, another electrocardiogram showed complete left bundle branch block and rather frequent auricular ectopic beats. There were no clinical indications that the heart had suffered any injury during this interval.

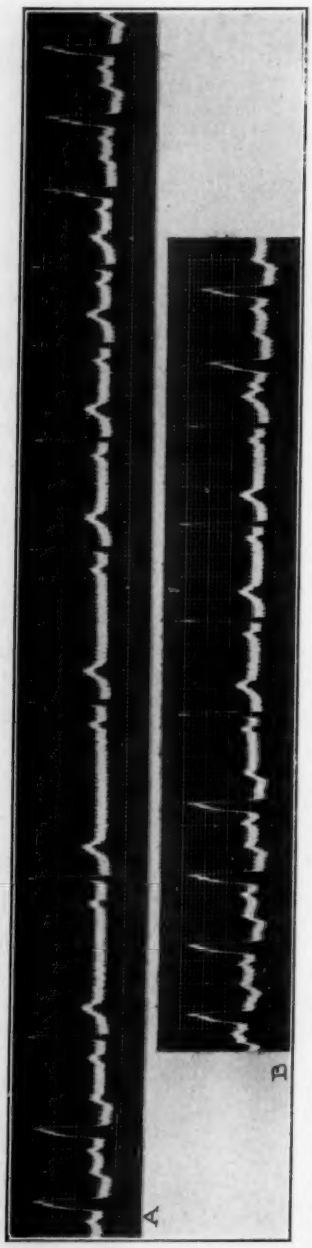


Fig. 1.—Lead I. Effect of vagal stimulation in neck on bundle branch block. *A*, Left carotid sinus pressure. Coincidental with slowing of the rate intraventricular conduction became normal. There is also prolongation of the P-R interval. *B*, Right carotid sinus pressure. Reduction in rate again brought about normal conduction.

The rate was somewhat faster, about 107 per minute. During the ensuing ten days electrocardiograms were repeated at frequent intervals, and, at times, they showed bundle branch block, while at other times there was normal conduction. Normal

conduction tended to be present at slow rates, and block at high rates of beating. While bundle branch block was present, observations were made on the effect of carotid sinus pressure and the administration of atropine intravenously. Fig. 1 shows the effect of carotid sinus pressure, and demonstrates the importance of a long diastolic pause in the recovery of conduction. This is further shown by Fig. 2, wherein two auricular ectopic beats occurred during a period of bundle branch block. The pause following one is only 0.02 second longer than that following the other. Fig. 3 *B* was taken four minutes after the intravenous injection of 3 mg. (gr. $\frac{1}{20}$) of atropine sulfate, and shows sinus tachycardia with 2:1 bundle branch block. This phenomenon persisted for eight minutes, when gradually the normal QRS complexes became transitional, then, finally, all complexes showed bundle branch block. During this time there was no significant variation of the blood pressure, and the full physiologic effect of the atropine was attested by dilation of the pupils and dryness of the mucous membranes.

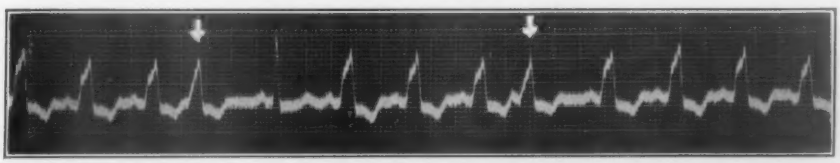


Fig. 2.—Lead I. Two auricular premature beats, illustrating the importance of a long diastolic pause as a factor in recovery of conduction. The pause preceding normal conduction measures 0.56 second, while that preceding the blocked impulse following the second premature beat measures 0.54 second.

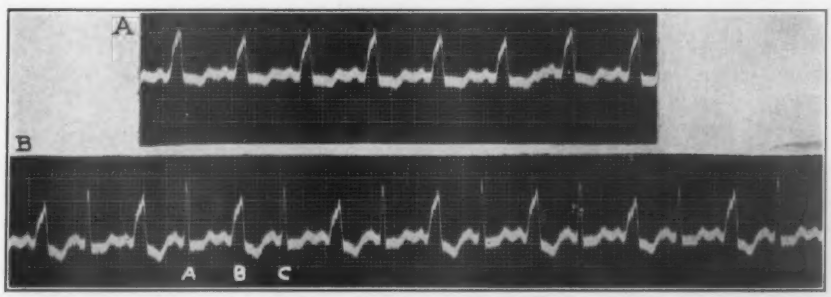


Fig. 3.—Lead I. Effect of atropine on bundle branch block. *A*, Taken immediately before injection. Rate about 100 per minute. *B*, Taken four minutes after the injection of 3 mg. of atropine sulfate intravenously. Rate about 140 per minute.

Following iodine therapy the pulse rate was persistently slower and the electrocardiograms persistently showed normal conduction, though bundle branch block could be made to reappear by accelerating the pulse by exercise.

The patient was transferred to the surgical service, and there underwent an uneventful thyroidectomy.

DISCUSSION

The subject of paroxysmal bundle branch block has recently been discussed by Comeau, Hamilton, and White,[2] and need detain us only long enough to emphasize the importance of a rapid rate of beating on the production of block in branches which are able to conduct normally if allowed a suitable recovery period.

Few reports of 2:1 bundle branch block with normal sinus rhythm have appeared in the literature; among them are the cases reported by Leinbach and White[3] and Kelly.[4]

That stimulation of the vagus nerves can produce A-V block and that atropine can increase conductivity through A-V tissues is now well known, but whether this also holds for the bundle branches is certainly unsettled. We have already seen that normal conduction could be made to appear in this patient by sufficient lowering of the cardiac rate, and that as the time for recovery grew shorter with an increasing rate, conduction through the bundle became impaired. It is of some interest, therefore, to see that the administration of atropine can bring about normal conduction in alternate cycles in spite of a significantly increased heart rate.

The evidence for decremented conduction in the A-V tissue is not conclusive, so that it seems best not to suggest such an explanation, as Drury and Mackenzie did. It may well be that future observations will confirm the presence of decremented conduction and its control by vagal tone.

A second possible explanation involves a change in conductivity and refractory period in the bundle branches themselves. This explanation would be more impressive had the conduction become entirely normal, for it is readily apparent that the interval from *A* to *C* (Fig. 3) is well over that at which normal conduction occurred at slow rates. Hence no such mechanism need be invoked. Furthermore, this mechanism might be expected to affect both branches equally. Since the appearance of bundle branch block complexes does not necessarily imply complete block, but simply that the impulse arrives by way of the undamaged branch before it can pass the damaged one, any factor which affects conduction in both branches might be expected to leave the excitation of each ventricle and the form of the electrocardiogram unchanged.

A third, and perhaps the most likely explanation is that the mechanism is dependent on change of rate *per se*. It is apparent that during periods of block the impulse must have passed far enough into the damaged branch at each cycle to maintain some degree of refractoriness. If the rate is now sufficiently increased, impulse *B* (Fig. 3) will arrive during a period of high degree of refractoriness and may be completely blocked. Under these circumstances the recovery of the area is not interrupted, so that impulse *C* may then be able to pass. This, of course, is simply what is thought to occur in 2:1 A-V block, except that in that case no alternative pathway is open to the impulse.

CONCLUSION

A case of paroxysmal bundle branch block associated with hyperthyroidism is reported.

During a period of block the administration of atropine converted the mechanism into 2:1 bundle branch block.

The possible underlying mechanisms are discussed, and the conclusion reached that change in rate, quite apart from any local effect of atropine, may be sufficient to produce this phenomenon.

REFERENCES

1. Drury, A. H., and Mackenzie, D. W.: Aberrant Ventricular Beats in the Dog During Vagal Stimulation, Quart. J. Exper. Physiol. 24: 237, 1934.
2. Comeau, W. J., Hamilton, J. G. M., and White, P. D.: Paroxysmal Bundle Branch Block Associated With Heart Disease, AM. HEART J. 15: 276, 1938.
3. Leinbach, R. F., and White, P. D.: Two-to-One Right Bundle Branch Block, AM. HEART J. 3: 422, 1938
4. Kelly, L. W.: Two-to-One Right Bundle Branch Block, AM. HEART J. 6: 285, 1930.

In Memoriam

JAMES WALLACE ESLER
1894-1938

PIONEER IN CARDIOLOGY IN WASHINGTON, D. C.

Many devoted patients and associates have been greatly saddened by the death, on Dec. 15, 1938, of James Wallace Esler, of Washington, D. C. Born October 27, 1894, in Tarentum, Pa., son of James M., and Katherine Esler, and educated in the public schools of Tarentum and at Washington and Jefferson College (A.B. 1916), he was graduated from the Medical School of the University of Pennsylvania in 1920. Research in physiology at the medical school, followed by two years' interneship at Pennsylvania Hospital, led him in 1923 to begin the practice of medicine in his home town, and for five years he built the foundation there, and in Boston, for the special field of cardiology, which he entered in the city of Washington in the fall of 1928.

It was our privilege in Boston early in that year of 1928 to have James Esler come to us as a graduate student and research associate in the cardiac clinics and laboratory of the Massachusetts General Hospital. He revealed to us during his stay not only the ability and industry that gave promise of the career that was fulfilled in the decade to come, but also the charming personality that endeared him to all who came in contact with him.

Modest, capable, thoughtful, and patient, he established himself in Washington as a pioneer in the special field of heart disease and left a place in the medical profession there which will be difficult to fill. He was Professor of Cardiology and Associate in Medicine at Georgetown University School of Medicine, member of the staffs of the Georgetown University, Garfield Memorial, and Emergency Hospitals, past president of the Washington Heart Association, and member of the District of Columbia Medical Society, Clinico-Pathological Society, and Osler Society of Washington.

Married Aug. 12, 1929, to Miss Lillian McGlasson, of Glendale, Ky., he has handed on his name to his son, who was born in 1933.

Many of James Esler's old friends join me in this tribute to his memory.

Paul D. White

Department of Reviews and Abstracts

Selected Abstracts

Kirch, E., and Nürmberger, W.: Development and Recession of Experimental Athlete Cardiac Hypertrophy. Arch. f. Kreislauf. 4: 1, 1939.

Studies were carried out on twenty-two rats who were subjected to swimming and running exercises. A definite hypertrophy was found which was proportional to the intensity of the exertion. With the severest exertion, the hypertrophy appeared in six days. Hypertrophy begins in the right ventricle and is most marked in this chamber. The right auricle is next involved, and usually also the left ventricle, and occasionally the left auricle. Running causes more hypertrophy of the left heart than swimming. The hypertrophy is accompanied by enlargement and elongation of the heart and involves the right heart more than the left.

In five rats, intensive exercise was carried out followed by five to six months of normal activity. In these animals, the cardiac dilatation and hypertrophy had disappeared. However, one animal showed a residual hypertrophy after 153 days of rest.

KATZ.

Rothberger, C. J., and Sachs, Arpad: Rhythmicity and Automatism in the Mammalian Left Auricle. Quart. J. Exp. Physiology 29: 69, 1939.

Mechanical records and electrograms taken from isolated strips from the left auricle of the heart of rabbits or guinea pigs show that the left auricle may beat spontaneously, although the histologic examination following the experiment fails to show specific nodal tissue in them. This examination was done by Professor Aschoff. These strips respond to stimulation by single condensor discharges or faradic current sometimes with an outlasting rhythm. Adrenaline and histamine produce sometimes, strophanthine never, and barium chloride, veratrine, and aconitine always a rhythmic activity, sometimes of long duration. In man, under pathological conditions, the left auricle may possibly initiate automatic contractions; single auricular extrasystoles or auricular tachycardias, especially those with a negative P wave in the electrocardiogram, may therefore, as Rothberger and Winterberg supposed long ago, originate in the left auricle.

AUTHORS.

Hamilton, W. F., and Dow, Philip: An Experimental Study of the Standing Waves in the Pulse Propagated Through the Aorta. Am. J. Physiol. 125: 48, 1939.

A technique is described for recording, directly and adequately, simultaneous pressure pulses from different parts of the open or occluded system comprising the aorta and the iliac and femoral arteries of intact dogs.

Series of records taken by this method present the following findings: a) The pulse pressure increases gradually from the aortic arch to the femoral, although the mean pressure remains constant.

b) The augmented systolic peak is not simply a propagated wave but is stationary. Beyond a nodal point somewhere in the thoracic aorta it occurs simultaneously at

all points in the system. The time from the start of the wave at the root of the aorta to the time of this stationary peak is a characteristic function of the length and the elastic properties of the central arteries, probably as far out as the knee.

c) Along with the formation of this stationary peak, and following it in the pulse cycle, there develop alternate falls and rises of pressure which reciprocate with simultaneous rises and falls at the root of the aorta.

d) By moving an occlusion down the aorta, the nodal point between these reciprocating divisions of the system can be shifted in the same direction.

e) The transformations in form and pressure undergone by the pulse in its travel toward the periphery are thus experimentally shown and their cause is identified. By reflection of the propagated wave, with changes in the volume-elasticity properties of the vessels through which it goes, certain components of it resonate, and the standing waves so produced are superimposed upon the fundamental pulse form.

It is shown that in the light of these experiments the application of sound physical principles permits a reconciliation of many controversial lines of emphasis in this field.

AUTHORS.

Dow, Philip, and Hamilton, W. F.: An Experimental Study of the Velocity of the Pulse Wave Propagated Through the Aorta. Am. J. Physiol. 125: 60, 1939.

Derived from records obtained by previously described methods, continuous curves are presented which show the changes in pulse wave velocity from aortic arch to femoral artery in seven dogs.

The wave is shown to accelerate quite evenly over this range, with considerable variation in the rate of acceleration in different dogs.

Measurements of the elasticity of rings cut from an aorta give results which are consistent with such an acceleration.

The pulse wave velocity corresponds to different functions of the diastolic pressure in the thoracic and abdominal portions of the aorta.

Stimulation of the vagus nerves, whether electrical or reflex, is accompanied by a slowing of the pulse wave in addition to that produced by the lowering of the diastolic pressure. In the records available so far, this effect is evident at low and normal pressures in the abdominal aorta and at higher pressures in the thoracic aorta.

The only hypothesis that can be put forward in explanation at present is that with vagus stimulation either nervous or hormonal influences bring about a change in the elasticity of the arterial wall by varying the tone of smooth muscle fibers.

AUTHORS.

Graybiel, Ashton, and White, Paul D.: Diseases of the Heart: A Review of Significant Contributions Made During 1938. Arch. Int. Med. 63: 980, 1939.

This important review summarizes briefly all the contributions made to the cardiac literature in the past year.

MCCULLOCH.

Hamilton, W. F., Woodbury, R. A., and Vogt, Elkin: Differential Pressures in the Lesser Circulation of the Unanesthetized Dog. Am. J. Physiol. 125: 130, 1939.

A modification of the London technique for placing angiostomy cannulae upon the pulmonary vessels, an advantageous device for administering artificial respiration and the technique for making optical tracings of the pressures in the pulmonary artery and vein of unanesthetized dogs are described.

By means of differential and ordinary "hypodermic" manometers, records were made of the pressures in the pulmonary artery, and pulmonary vein, of the effective

pressures distending these vessels within the thorax and of the gradient of pressure forcing blood through the lungs.

In normal unanesthetized dogs, breathing quietly, the pulmonary arterial pressure varies between 45/12 and 28/7 mm. Hg in different dogs and averages 37/10. The mean pressure (integrated) averages about 20 mm. Hg. The pulmonary venous pressure, taken during quiet breathing, averages 3 to 12 mm. Hg.

Inspiration lowers total pressure in both the systemic and pulmonary arteries, but raises slightly the effective pressure in the pulmonary artery. The total pressure in the pulmonary vein is lowered by inspiration but the effective pressure is changed very little. The expiratory increase in systemic arterial pressure is caused partly by an increase in intrathoracic pressure and partly by an increase in cardiac output.

The gradient of pressure forcing blood through the lungs is decreased by a prolonged rise in intrathoracic pressure and increased immediately afterwards. It is also increased by air embolism. It is unaffected by this gradient. Secondary effects due to changes in blood flow are so small as to imply very definitely that the pulmonary channels are quite capacious.

The rise in pulmonary arterial pressure after large doses of epinephrine is due to back pressure from the left ventricle and is not accompanied by an increase in the gradient of pressure from artery to vein. We can supply no clear cut evidence that vasoconstriction in the pulmonary bed plays any significant role in the dynamics of the lesser circulation.

AUTHORS.

Wright, G. W., Hallaran, W. R., and Wiggers, C. J.: The Economy of Effort Index for Hearts of Normal and Hypertensive Subjects. Am. J. Physiol. **126**: 89, 1939.

A method, based upon a principle worked out from animal experiments by Wiggers and Katz, is suggested, by which the economy of effort during ejection of the normal human left ventricle can be expressed and compared with that of the ventricle of a hypertensive subject.

Reconstruction of the ejection phase of the intraventricular pressure curve is accomplished using the subclavian pulse curve for contour and applying simultaneously obtained brachial artery pressures for the ordinate (pressure) values. The surface area of the curve above diastolic value divided by that beneath this area offers a quotient expressing the economy of ventricular effort during ejection.

Results for eighty-one normal individuals indicate a wide variation in the quotient (0.215-0.880) and it is greatest in those subjects having a comparatively large pulse pressure and a low diastolic pressure. This wide variation is explained by the normal variation in the relation of systolic discharge to peripheral resistance.

Results for fifty-four individuals with chronic hypertension show an even greater range of quotient (0.220-1.030) and the same relation to pulse pressure and diastolic pressure is observed as was found in the normal individuals. A larger number of this group had a quotient above the median (0.428) of the normal group. The conclusion is reached that the left ventricle in hypertension maintains a quotient as good as, or even better than, that of the normal left ventricle by virtue of a large pulse pressure and in spite of an elevated diastolic pressure.

Evidence is given in support of the belief that decreased distensibility of the aorta when found in conjunction with hypertension, particularly in older subjects, supplies a mechanism whereby the economy of effort during ejection remains normal or may actually become more favorable.

AUTHORS.

Leriche, René, Fontaine, René, and Friedmann, Leon: Is Stellate Infiltration in Pulmonary Embolism Justified From the Physiological, Anatomical and Pathological Points of View? What Place Should It Occupy in the Therapeusis of This Condition? Jour. de Chirurgie 50: 47, 1937.

The authors report treatment of three cases of pulmonary embolism by anesthetization with novocain of the stellate ganglia. Good results were noted once, failure occurred twice. They believe that vasoconstrictive reflex is set up by the embolus which in itself does not seem sufficient to cause death in many instances. They point out the differences of effect on circulation of ligation of the femoral artery and occlusion of it by an embolus, and they feel that in the latter condition there is complementary vasospasm. The authors believe that the pulmonary arteries receive their vasomotor fibers from the cardiac plexus which in turn receives many fibers from the stellate ganglia. They believe that on an average one out of each three cases of pulmonary embolism might be greatly benefited by the procedure mentioned above. They believe that all physicians should be taught to perform anesthetization of the stellate ganglia immediately in cases of pulmonary embolism.

ALLEN.

Schlomka, G., and Konigs, G.: Relative Duration of Systole. V. In Heart Muscle Disease. Ztschr. f. Kreislaufforsch. 30: 825, 1938.

The duration of systole is usually relatively longer when the heart muscle is damaged, especially in older people. In a few, when related to heart rate, there is an abnormal short duration of systole, and these are the ones with poorly functioning hearts.

KATZ.

Latzel, M.: Relative Duration of Systole in Hot Baths. Ztschr. f. Kreislaufforsch. 30: 865, 1938.

The relative duration of systole (with respect to heart rate) using the cube root formula of Fridericia, decreased in hot baths of 42° C.

KATZ.

Scherf, David, and Kisch, Franz: Ventricular Tachycardias With Variform Ventricular. Bull. New York Medical College 2: 73, 1939.

A series of eighteen cases of ventricular tachycardia with alternation of the form of the ventricular complexes, sometimes combined with a change or true alternation of the length of the diastoles, have been observed. They may be classified into three groups: regular alternation of two different forms of the ventricular complex and a regular rhythm; regular alternation of two forms as well as of the length of the diastoles; a complete irregularity of the form and sometimes also of the rhythm of the ventricular extrasystoles.

Comment was made upon the various explanations which have been advanced for these cases and it was shown that in every type a single center of stimulus formation may exist while the abnormal picture may be caused simply by a disturbance of intraventricular conduction. This is proven by the observation of two cases in which beats originating in the auricle were abnormally conducted to the ventricle in such a manner that all three of the types of tachycardia were imitated. The assumption that the formation of a stimulus in the ventricle itself may be followed by similar disturbances of conduction is entirely comprehensible.

Apart from very rare exceptions, myocardial changes always exists in cases of this kind. In addition the use of digitalis is found an initiating factor in a majority of the cases. Even small doses of digitalis may produce these tachycardias at times.

One case was described in which such a tachycardia was observed over a period of five years; necropsy failed to reveal any pathologic change in the heart save a marked dilatation, the consequence of the tachycardia.

AUTHORS.

Cowan, John: Some Disturbances of the Rhythm of the Heart. Brit. Heart J. 1: 3, 1939.

Sino-auricular block is not necessarily accompanied by cardiac symptoms. Four cases came under observation on account of symptoms other than cardiac; nine cases on account of cardiac symptoms. The heart may be apparently sound (six cases); or may show signs of organic heart disease (seven cases).

Sino-auricular block can only be recognized by polygraphic or electrocardiographic examination. It may be suspected as the cause of recurrent syncopes in patients who show, between attacks, gross sinus irregularity.

The presence of sino-auricular block does not affect the cardiac prognosis or treatment in the individual case; which must be based upon the general rather than the cardiac picture.

AUTHOR.

Wood, Paul, and Selzer, A.: Chest Leads in Clinical Electrocardiography. Brit. Heart J. 1: 49, 1939.

The normal appearances of electrocardiograms obtained with Lead IV R have been presented.

Five other chest leads were investigated: Lead IV F; the left pectoral—right arm lead; the left pectoral—left leg lead; the right pectoral—right arm lead; and the right pectoral—left leg lead.

Limb lead and multiple chest lead electrocardiograms were obtained from 302 selected cases of heart disease, and from twelve cases of cardiac displacement due to a high diaphragm.

In addition to their value as an aid in the recognition of ischemic heart disease, chest leads have been found of service in the diagnosis of rheumatic carditis, pericarditis, left ventricular enlargement, right ventricular enlargement, acute cor pulmonale resulting from pulmonary embolism, and of doubtful or bizarre forms of bundle branch block.

The right arm was both the most informative and the most convenient site for the distal electrode; and we believe that the evidence is now sufficient to warrant its routine use in preference to the left leg. The latter was only advantageous when it was desired to distinguish left ventricular enlargement from cardiac displacement due to elevation of the diaphragm.

Multiple chest leads are of value not only because they may yield diagnostic evidence of myocardial infarction when a single chest lead is barren, but also because they are a safeguard against faulty interpretation of Lead IV, because each of the three leads (Lead IV and the two pectoral leads) used in this investigation has some special value peculiar to itself, and because a study of these three leads in relation to one another may give information which is unobtainable by a study of individual leads.

AUTHORS.

Robinson, Roger W., Contratto, A. W., and Levine, Samuel A.: The Precordial Lead. Arch. Int. Med. 63: 711, 1939.

A study was made to ascertain which point over the precordium could be used in taking the so-called Lead IV that would furnish the most reliable information in the diagnosis of myocardial infarction. For this purpose nine or ten tracings were taken with the electrode in various parts of the precordium in each of 352 cases. The two main criteria that were analyzed were the presence or absence of the Q wave and the direction of the T wave. In this study tracings were regarded as indicative of myocardial infarction if the Q wave was absent. They were called questionably indicative of infarction if the Q wave was less than 2 mm. deep. The term abnormal was used when a normal Q wave was present but the T wave was upright. It was found that interpretations of the electrocardiograms obtained with the electrode over the base of the heart and along the sternum were often misleading. The error decreased as the apical region was approached. It was also found that the electrocardiograms obtained with the electrode in the region of the nipple or in the midclavicular line, although generally reliable, were frequently not so when there was considerable cardiac hypertrophy. The only lead that gave a curve for which a satisfactory interpretation could be made with an extreme degree of accuracy was the one for which the electrode was placed over the apical impulse of the heart.

For seventy-five persons with normal hearts the Q wave was normally present and deepest with the apical lead. With the other positions it was often small (less than 2 mm.) and rarely absent. The T wave was frequently upright with many of the precordial positions and in four instances even with the apical lead.

Deep inspiration was found to shorten the Q wave and to change an inverted to an upright T wave in some instances. More reliable information could be obtained during normal breathing than during deep inspiration.

Although minor differences in the electrocardiograms were noted with the patient in the supine, upright, left lateral or right lateral position, these did not alter the accuracy of the interpretations with the apical lead.

It was found that when fluid was present in the left pleural cavity, an absent or small Q wave might become normal after thoracentesis.

The removal of fluid from the abdomen changed a small Q wave to a normal one.

When the heart was considerably enlarged, owing to vascular disease, hypertension or other causes, frequently there was no Q wave with any of the precordial leads except the apical. The T wave was often upright even with the apical lead.

Two patients with syphilitic narrowing of the coronary ostia without myocardial infarction showed a Q wave of only 0.5 mm. with the apical lead.

The presence of auricular fibrillation or delayed intraventricular conduction did not interfere with the correct interpretation of the fourth lead. In two of the eleven cases of left bundle branch block the method of interpretation of Lead IV used in this study was incorrect.

It can be concluded that, except in the rare instances cited, a Q wave of 2 mm. or more in the electrocardiogram with the apical position will always be found when the heart is normal or when there are various forms of heart disease unassociated with anterior myocardial infarction.

AUTHORS.

Braun-Menendez, E., and Solari, L. A.: Ventricular Asynchronism in Bundle Branch Block. Arch. Int. Med. 63: 830, 1939.

Bundle branch block experimentally produced in dogs is followed by marked ventricular asynchronism, and it may be assumed that the same happens in human beings with bundle branch block.

Optical recording of the apex beat, the venous pulse, the heart sounds, and the central arterial pulse simultaneously makes it possible to recognize whether or not the ventricles beat synchronously or, in the absence of synchronism, which ventricle contracts first.

Investigations carried out in this way have demonstrated that the electrocardiographic alterations which, according to the older view, were considered as characteristic of right bundle branch block are, in fact, encountered in cases of left bundle branch block.

Electrocardiograms with all the characteristics of bundle branch block may exist without there being any detectable asynchronism and hence without there being complete block.

In conclusion, it may be advanced that the electrocardiogram which shows pronounced alterations affords a good evidence of intraventricular block. However, it does not offer a reliable means for establishing a diagnosis of complete bundle branch block, or, furthermore, for the localization of the branch involved. The adequate recording of the mechanical events due to cardiac action affords the only means for determining the existence of ventricular asynchronism, thereby allowing the recognition of delayed excitation through one of the bundle branches and the localization of the functional disturbance.

AUTHORS.

Vander Veer, Joseph B., and Edwards, Joseph C.: The Significance of Small and Absent Initial Positive Deflections in the Chest Lead. Am. J. M. Sc. 197: 663, 1939.

The electrocardiograms and clinical histories of 102 patients with an absent initial positive deflection in the precordial lead (*R* wave of new and Q wave of the old technique), and forty-six patients with a small initial positive deflection (2 mm. or less) have been reviewed.

The most frequent cause of an absent initial positive deflection (67 per cent) was a previous anterior myocardial infarction. In the other patients with this abnormality, organic cardiovascular disease was present in all instances, usually arteriosclerotic or luetic heart disease, with or without hypertension. Cardiac enlargement and myocardial damage from other causes may also be factors causing disappearance of this wave.

When the initial positive deflection is absent in the precordial lead, the QRS complex rarely returns to normal. An absent initial deflection may be followed by a small initial deflection in some cases of myocardial infarction, and occasionally either of these signs may be the only residual electrocardiographic finding in this condition.

A small initial positive deflection in the precordial lead (2 mm. or less) is a less important sign than an absent one. It is occasionally seen in normal hearts but usually is of similar significance to an absent initial positive deflection.

The importance of proper application of the precordial electrode is emphasized, especially in relation to the size of the initial positive deflection of the QRS complex.

A correlation between the T-wave findings in the precordial lead and Lead I with the absent and small initial positive deflections shows a larger per cent of abnormal T waves in the absent deflection group. The presence of an abnormal T wave in one or both of these leads with a small or absent deflection in the precordial lead makes the latter sign of greater significance. In general, T-wave abnormalities are less permanent than the QRS abnormalities in the precordial lead.

AUTHORS.

Van Nieuwenhuisen, C. L. C., Hartog, H. S. Ph., and Matthijssen, E.: New Diagnostic Features in the Four Lead Electrocardiograms of Angina Pectoris. Acta Scandinav. Med. **98:** 468, 1939.

This is one of a series of articles on the diagnostic points of electrocardiography. Amongst 5,500 curves, the authors selected for further study 355, presenting peculiarities which they considered suggestive of disease.

Fifty-one electrocardiograms met Pardee's criteria for deep Q_3 waves. They assumed that coronary sclerosis was present in 84 per cent of these; twenty-four of them suffered from angina pectoris, twenty-four had congestive failure, eleven of them had both together.

They included W- and M-shaped complexes in Lead III, though they admitted that they were more significant in Lead II. In the presence of marked left cardiac dilatation, left axis deviation might be obscured by Pardee's Q waves or by W- or M-shaped complexes.

Sixty-three tracings showed W-shaped complexes (fifty-eight in Lead III, five in Lead II). Of these, twenty-four had hypertension, twenty-four cardiac failure, and twenty-nine angina pectoris. Seven had both angina pectoris and cardiac failure.

Ten showed M-shaped complexes (one in Lead I, three in Lead II, six in Lead III). Seven of these had some decompensation and three also angina pectoris.

More original are the observations on the "notch at the foot of the R" which the authors consider the result of a rotation of the axis of the "S," causing it to become positive. It occurred fifty-seven times, mostly in men, and above the age of 50 years. About one-half the cases had hypertension, one-third congestive failure, and one-half angina pectoris. Often there were other signs of coronary disease. It occurred most commonly in Leads I and II, rarely in III. In almost all cases presenting this change there was reason to suspect heart disease. The notch was observed to appear following coronary occlusion and, once, to precede it. Then it appeared during effort only. It was also observed following cardiac shock, just after the clonic phase.

They associated the "saddle shaped S-T segment" with myocardial changes, but they failed to define it accurately. In some cases they considered it a less developed form of the preceding change, and they surmised that the two irregularities had a common cause. The saddle shaped S-T segment occurred in 102 cases, in sixty-six of these they thought other clinical data justified a diagnosis of coronary sclerosis, and in ten others there was evidence of other heart disease. In many cases the patients had what appeared to be functional complaints. The authors seemed less certain of the significance of this finding; certainly in the absence of control material or autopsy findings, this point requires further study.

T waves exceeding in height one-half of the R waves in the same standard had occurred in twenty-seven tracings. Eight complained of angina pectoris, five of congestive failure. Coronary sclerosis was thought to be present in fourteen. In the absence of thyrotoxicosis and mitral stenosis, the authors considered "tall T waves" an important sign.

Chest leads were taken with the right arm electrode in fourth left intercostal space and with left leg electrode. The changes seen in coronary thrombosis may also be seen in coronary sclerosis, possibly indicating a similar but slower process. Dilatation of the left ventricle may cause a shallow Q wave, unless the electrical axis takes a longitudinal position (youth, mitral stenosis). Shallow Q waves may also result from coronary sclerosis. Deep Q waves in the chest lead, in the absence of a longitudinal axis in the standard leads, indicate coronary sclerosis. Deep Q waves in the chest leads occurred in forty-five patients. Twenty patients had

congestive failure, eighteen angina pectoris. In thirty-one, coronary sclerosis was obvious, so the authors considered this sign important.

Appended is a large collection of electrocardiograms. The suggestions contained in this paper are stimulative, but require definitely further checks and controls before they can be accepted.

JENSEN.

Allen, Arthur C.: Mechanism of Localization of Vegetations of Bacterial Endocarditis. Arch. Path. 27: 399, 1939.

In from 50 to 75 per cent of cases bacterial endocarditis is superimposed on rheumatic endocarditis. Rheumatic endocarditis commonly produces a valvular fibroplastic deformity with stenosis. This lesion takes the form of a projecting shelf or barrier, usually at the line of closure, against which the blood stream strikes. By virtue of this obstruction to the systolic discharge (manifested by myocardial hypertrophy) the site of the deformity suffers a distinctly greater impact and contact than the normal valve leaflet, which "gives" or yields with the stream. This contact with the blood (and organisms in a bacteremia) is further enhanced by the diastolic backflow due to insufficiency, the usual concomitant of stenosis. The role of these dynamics in the localization of vegetations is suggested.

This same mechanism applies to congenital lesions including the "so-called congenitally bicuspid aortic valve."

Attention is called to the fact that the outflow surface of all valves, normal or deformed, comes in contact with a much greater area of blood (and toxic agents) than the opposite surface. The significance of this in the localization of vegetations is stressed.

An explanation based on the same principles is offered for the rarity with which auricular fibrillation is complicated by bacterial endocarditis. The possibility of the influence of other auxiliary factors is not precluded.

It is pointed out that there is an increased tendency for acute rather than subacute endocarditis to occur on (a) valves not previously deformed and (b) valves of the right side of the heart. This fact is correlated with the principles of impact and contact.

AUTHOR.

Stewart, Harold J., and Heuer, George J.: Chronic Constrictive Pericarditis. Arch. Int. Med. 63: 504, 1939.

An analysis of the clinical manifestations in nine cases of chronic constrictive pericarditis has been given. In seven of these cases partial pericardiectomy was performed. The presence of this syndrome should be considered when there are signs of congestive heart failure in the absence of the usual causes of failure. Three of the patients appear to be "cured"; three others are greatly improved, and the seventh is now convalescing from the operation. Studies of the circulation have shown that this syndrome is associated with a decrease in the cardiac output per minute and per beat, a rise in the venous pressure and a slowing of the velocity of the blood flow. These alterations are related to the obstruction to the flow of blood into the heart, i.e., to interference with diastolic filling, and to interference with contraction, by the thickened, adherent pericardium. With the institution of pericardial resection and the subsequent clinical improvement, the measurements of the circulation undergo parallel changes toward or to normal. There is parallelism in these cases between the clinical manifestations and the objective measurements of the circulation. Experience in these cases leads the authors to recommend surgical treatment.

AUTHORS.

Woodbury, R. A., Robinow, M., and Hamilton, W. F.: Blood Pressure Studies on Infants. Am. J. Physiol. 122: 472, 1938.

Optical registrations of arterial pressure pulses were obtained by the "hypodermic manometer" from thirty-seven newborn babies. The same systolic values could be obtained by cuff and palpation if the arm band was 2.5 cm. wide. The conventional cuff of pediatricians gave systolic readings 20 to 25 mm. Hg too low.

The blood pressures of twenty-four full term newborn infants averaged 80/46 mm. Hg. The standard deviation of a single observation was 8.1 mm. Hg (systolic) and 8.2 mm. Hg (diastolic).

The infant's blood pressure was found to be not significantly affected by the following: 1, obstetrical anesthesia; 2, the onset of respiration; 3, clamping the cord after birth, and 4, administration of CO_2-O_2 to the baby.

The infant's blood pressure was affected slightly but significantly by the following: 1, blood pressure level of the (normal) mother $r = 0.303 \pm 0.063$ (diastolic); 2, toxemia of pregnancy (+10 mm. Hg systolic, +3 mm. Hg diastolic); 3, amyl nitrite administered to baby (-8 mm. Hg systolic, -7 mm. Hg diastolic), and 4, epinephrine, intravenously, 0.2 mg. (+10 mm. Hg systolic, +7 mm. Hg diastolic).

The infant's blood pressure was markedly affected by the following: 1, crying (+10 to 45 mm. Hg systolic and diastolic); 2, dehydration without collapse (+30 mm. Hg systolic); 3, administration of fluid to dehydrated babies (-30 mm. Hg systolic); 4, age of infant, and 5, degree of prematurity.

AUTHORS.

Gavey, C. J., and Parkinson, John: Digitalis in Heart Failure With Normal Rhythm. Brit. Heart J. 1: 27, 1939.

This investigation was undertaken primarily to decide the clinical value of digitalis in heart failure with normal (sinus) rhythm. The secondary purpose was to compare its value in such failure with that in auricular fibrillation, which is better known.

Sixty-five patients with heart failure and normal rhythm were observed. After one week or more at rest in bed, digitalis leaf was given in a dose of 2 grains three times a day, i.e., 6 grains (0.4 gm.) daily, for one to two weeks. The condition at the beginning of digitalis treatment was compared with that at the end. The criteria of failure were dyspnea, liver enlargement, and edema with or without hydrothorax; and judgment as to improvement was made on these criteria together with diuresis. Reduced heart rate was not reckoned as a criterion, and it is separately considered. Twenty-five patients had hypertensive heart disease, 12 with and 13 without past coronary thrombosis; 11 had chronic rheumatic valvular disease; 9 had syphilitic heart disease; and 2 were unclassified. In these, the main groups, the majority, 72 per cent, had edema at the end of the week's rest in bed and a quarter of these had hydrothorax, confirmed by x-ray examination.

The control lay in the preliminary rest in bed without digitalis; but for comparison another series of 30 patients with failure and auricular fibrillation was observed in the same way.

Under rest in bed only, in normal rhythm, 17 of 47 (36 per cent) improved; in auricular fibrillation, 11 of 28 (39 per cent) improved.

The main digitalis results are shown by a table, and there are illustrative charts of effect and of failure of effect. In normal rhythm some clinical improvement was demonstrated in 35 out of 58 tests (60 per cent); and 23 of 58 showed none. Admittedly 17 received only slight benefit, so that moderate or great benefit resulted in 18 only, i.e., 31 per cent of the whole. There was little difference in response among the separate etiological groups, though the rheumatic group responded best.

The heart rate in failure with normal rhythm is moderate, the average in our series before digitalis being 85. It was reduced by digitalis in 27 out of the 58 tests (47 patients), i.e., in almost half (46.5 per cent). The average fall in rate among those in whom it occurred was from 85 to 67, i.e., 18. This was usually secured without toxic symptoms, and when these appeared (20 per cent) they were slight (nausea and rarely vomiting). Whatever the initial rate, digitalis often reduced it. Reduction in rate was not always accompanied by clinical improvement, though improvement was rather more common in the patient who showed it. Some good clinical results were seen without any reduction in rate.

Diuresis was induced by digitalis in 27 of 58 tests (47 patients) in normal rhythm. It was freer in patients with gross edema than in those with little or none; but some diuresis was obtained almost as frequently in those without as in those with edema.

The course of the disease after the onset of failure in normal rhythm is short—18 of 29 patients died within a year—and this in general must lessen the likelihood of improvement from digitalis. Yet in a particular patient the response to digitalis is no guide to the expectation of life; and if digitalis fails at a first trial, it may occasionally succeed at a later trial.

Of the patients with auricular fibrillation, 12 had hypertensive heart disease, 14 had chronic rheumatic valvular disease, and 4 were unclassified. Clinical improvement was demonstrated in 23 of 32 tests (30 patients), i.e., in 72 per cent; and 9 showed none. It was slight in nine, and moderate or great in fourteen, i.e., 44 per cent of the whole.

The heart rate was higher than in the normal rhythm series, an average of 98 against 85, a difference of 13. The rate was reduced by digitalis in the great majority, in 28 of 32 tests (87 per cent). The average fall in rate where a fall resulted was from 100 to 70, an average fall of 30. Most of those with slowing also showed benefit, but in the absence of slowing there was none.

The rheumatic group was distinguished by a higher average rate before treatment, by reduction of the rate in all fourteen cases, and by clinical improvement in all but two. Even with a moderate initial rate (below 100), results were better in rheumatic than in nonrheumatic fibrillation, though no better than in rheumatic cases with normal rhythm.

Without the rheumatic group, the fibrillation series responded to digitalis no better than the normal rhythm series. In hypertension, for instance, the results were similar.

A mercurial diuretic sometimes administered after a digitalis test nearly always produced a free diuresis even where digitalis had failed. In edematous patients other than those with rheumatic auricular fibrillation and a high ventricular rate, a mercurial diuretic usually has more value than digitalis. Yet a trial of digitalis cannot be omitted, for it alone acts directly on the heart. The partnership of a mercurial diuretic with digitalis should govern the treatment of heart failure.

Digitalis is always indicated in congestive heart failure irrespective of rhythm, but it is often inefficient, as it fails completely in about a third of all cases.

In heart failure with normal rhythm digitalis is helpful in rather more than half the cases.

In heart failure with auricular fibrillation, digitalis is more often helpful than it is in normal rhythm, for it benefits more than two-thirds. This superiority rests on its particular value in rheumatic heart failure with fibrillation, largely but not entirely due to the high ventricular rate. Incidentally, it is in this group that rate control by continued digitalis best prevents recurrence of the failure.

The real difference in the response of heart failure to digitalis lies not between auricular fibrillation normal rhythm, but rather between rheumatic auricular fibrillation and all other kinds of heart failure irrespective of rhythm.

AUTHORS.

American Heart Association, Inc.

RADIO CITY

50 WEST 50TH STREET, NEW YORK, N. Y.

DR. WILLIAM D. STROUD
President

DR. PAUL D. WHITE
Vice-President

DR. HOWARD B. SPRAGUE
Secretary

DR. WALTER W. HAMBURGER
Treasurer

BOARD OF DIRECTORS

DR. T. HOMER COFFEN — Portland, Ore.
DR. CLARENCE DE LA CHAPELLE — New York City
DR. WILLIAM DOCK — San Francisco
DR. HUGH FARRIS — St. John, N. B., Canada
DR. WALTER W. HAMBURGER — Chicago
DR. GEORGE R. HERRMANN — Galveston
*DR. EMMET F. HORINE — Louisville
DR. T. DUCKETT JONES — Boston
*DR. EMANUEL LIBMAN — New York City
DR. DREW LUTEN — St. Louis
DR. GILBERT MARQUARDT — Chicago
*DR. H. M. MARVIN — New Haven
*DR. EDWIN P. MAYNARD, JR. — Brooklyn
DR. THOMAS M. MCMILLAN — Philadelphia
DR. JONATHAN MEAKINS — Montreal
*DR. FRANKLIN NUZUM — Santa Barbara
DR. STEWART R. ROBERTS — Atlanta
*DR. ROY W. SCOTT — Cleveland
*DR. HOWARD B. SPRAGUE — Boston
*DR. WILLIAM D. STROUD — Philadelphia
DR. LOUIS VIKO — Salt Lake City
*DR. PAUL D. WHITE — Boston
DR. FRANK N. WILSON — Ann Arbor
*DR. IRVING S. WRIGHT — New York City
DR. WALLACE M. YATER — Washington, D. C.

DR. H. M. MARVIN, *Chairman, Executive Committee and Acting Executive Secretary*
GERTRUDE P. WOOD, *Office Secretary*
TELEPHONE CIRCLE 5-8000

THE American Heart Association, sponsor of the first International Health Broadcast, stands alone as the national organization devoted to educational work relating to diseases of the heart. Its Board of Directors is composed of twenty-five physicians representing every portion of the country.

The Section for the Study of the Peripheral Circulation was organized in 1935 for the purpose of stimulating interest in investigation of all types of diseases of the blood and lymph vessels and of problems concerning circulation of blood and lymph. Any physician or investigator in good standing may become a member of the section after election to the American Heart Association and payment of dues to that organization.

To coordinate and distribute pertinent information, a central office is maintained, and from it issues an ever widening stream of books, pamphlets, charts, posters, films, and slides. These activities all concern the recognition, prevention or treatment of the leading cause of death in the United States, diseases of the heart. The AMERICAN HEART JOURNAL is under the editorial supervision of the Association.

The income from membership and donations provides the sole support of the Association. Lack of adequate funds seriously hampers more widespread educational and research work imperative at this time. Great progress has been made, but much remains to be done.

Annual membership is $5.00 a year and journal membership at $10.00 includes a year's subscription (January-December) to the AMERICAN HEART JOURNAL and annual membership in this Association. A cordial invitation to join in this crusade is extended to you.

The American Heart Association solicits your support to the end that it may continue more effectively the campaign to which it has devoted all its energy.

**Executive Committee.*